PRINTED ON THIN PAPER FOR FOREIGN CIRCULATION

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

VOL. CXIII.—No. 2932.] *LONDON: FRIDAY, MARCH 10, 1922.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 3½d.

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AUTOMATIC FEED REGULATORS.
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Specification and Workmanship equal to Main Line Locomotives.
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See page 17. 9947

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Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 8746
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See Advertisement page 77, March 3.

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designed and constructed by MANNING, WARDLE AND COMPANY, LIMITED, Boyne Engine Works, Leeds. Od 2487
See their Illus. Advertisement, page 99, last week.
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S. H. HEYWOOD & CO., LTD., 9662 REDDISH.

John H. Wilson & Co., Ltd.,
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See Illustrated Advertisement Page 100, Jan. 26, 1921.

Locomotive Shunting Cranes

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EXCAVATORS, CRANE-NAVVIES, GRABS, CONCRETE-MIXERS, SHIPS' WINDLASSES, WINCHES, and DECK MACHINERY. 637
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GENERAL CONSTRUCTIONAL ENGINEERS,
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Stewarts and Lloyds, Ltd.,
Glasgow and Birmingham.
See Advertisement page 82. 9063

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HIGH BOILER EFFICIENCIES ARE OBTAINED BY INSTALLING
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FUEL OIL BURNING SYSTEMS, HEATERS, STRAINERS.
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London Office—12, Victoria Street, S.W.
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&c. &c. 9604

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Diesel Engines, Six Cylinder, two and four stroke, 350, 1000, 1200 HP. Excellent condition. Dynamos for above 250 or 500 Volts, D.C. Immediate delivery and low price.
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9564
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See Full Page Advt., page 64, March 3.

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Forgings, Castings, Bars, Sheets, Wire, Tubes.
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TAYLOR & CHALLEN, LTD., Engineers, Constitution Hill, BIRMINGHAM.
See Full page Advertisement page 66, March 3.

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Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND.
9727
See half-page Advertisement page 43, Feb. 17.

The Manchester Steam Users' ASSOCIATION.
For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by SIR WILLIAM FAIRBAIRN.
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Inst. C.E. Exams.—Successes as usual last Exam. by Correspondence Coaching. Successes by hundreds, several prizes. Sec. "O" embraces 25 years' professional experience. Address, 7434, Offices of ENGINEERING.

TENDERS.

SWANSEA HARBOUR TRUST.

The Swansea Harbour Trustees invite

Tenders for the Repair of certain FERRO-CONCRETE QUAYS in their King's Dock, by means of the Cement Gun. The quays may be inspected, and further particulars of the nature of the repairs to be executed may be obtained, on application to the Trustees' Engineer, Mr. A. O. SCHENK, M.I.C.E., Harbour Offices, Swansea.

Tenders, marked "Repairs to Quays," should be delivered to the undersigned not later than Ten a.m. on Friday, the 24th March, 1922.

The Trustees do not bind themselves to accept the lowest or any Tender.

TALFOURD STRICK,
Clerk.

Harbour Offices,
Swansea.
25th February, 1922. T 571

TO CONSTRUCTIONAL STEEL CONTRACTORS AND OTHERS.

THE METROPOLITAN ASYLUMS BOARD invite

Tenders for Erecting only STEEL FIRE ESCAPE BRIDGES and incidental works in connection at Tooting Bec Mental Hospital extension, Church Lane, Tooting, S.W. 17, in accordance with drawing and specification prepared by Mr. T. COOPER, M.Inst.C.E., M.I.Mech.E., Engineer-in-Chief. The Drawing, Specification and Form of Tender may be inspected at the office of the Board, Embankment, E.C. 4, and can be obtained upon payment of a deposit of £1. The amount of the deposit will be returned only after the receipt of a *bona fide* Tender sent in accordance with the instructions on the Form of Tender, and after the documents have been returned.

Tenders addressed as noted on the form must be delivered at the Office of the Board not later than 2.30 p.m. on Wednesday, 29th March, 1922.

(By Order)
DUNCOMBE MANN,
Clerk to the Board. T 676

COUNTY OF WEST SUSSEX.

NORFOLK BRIDGE OVER RIVER ADUR, SHOREHAM-BY-SEA.

TO BRIDGEWORK CONTRACTORS.

The West Sussex County Council is prepared to consider

Tenders for the Entire RECONSTRUCTION of the SUPERSTRUCTURE of the above BRIDGE under the West Sussex County Council (Bridges) Act, 1913, 3 and 9 Geo. V. c. XLI., together with the Partial Reconstruction of both Abutments, the Provision of One New Pier, and the possible Strengthening of Two Existing Piers.

The new superstructure will consist of four bow string girders, having an approximate total length of 530 ft., the roadway being 18 ft. in width and having two cantilever paths.

Contractors may Tender either—

(1). For the whole of the work.

(2). For the masonry and the demolition of the existing bridge only.

(3). For the steel work and its erection only.

Plans, Specifications, and Bills of Quantities may be seen at the Offices of the Consulting Engineers to the County Council, HOWARD HUMPHREYS & SONS, 28, Victoria Street, Westminster, S.W. 1, between the hours of Ten a.m. and Four p.m. on and after March 17th, 1922, until March 24th.

Contractors requiring Specifications and Quantities will be able to obtain the same by depositing Ten Guineas, with the above-named Consulting Engineers; such sum will be refunded on receipt of a *bona fide* Tender. Contractors may, if they wish, order a set of blue prints of the work at the time of inspecting the drawings and upon payment of the nett cost of the prints.

The successful Contractor will be required to execute a contract deed as prepared by the undersigned, the draft of which may be inspected at the Offices of the Consulting Engineers.

Tenders must reach the undersigned not later than Nine a.m. on Monday, April 3rd next, marked "Norfolk Bridge Tender," on the outside of the envelope.

The County Council does not bind itself to accept the lowest or any Tender.

Dated the 7th day of March, 1922.

S. THORNELY,
Clerk to the West Sussex County Council.

84, East Street,
Horsham. T 668

THE METROPOLITAN ASYLUMS BOARD invite

Tenders for Repairs to DOLPHINS at Long Reach Pier, Long Reach Hospital, Dartford, Kent, in accordance with specification prepared by Mr. T. COOPER, M.Inst.C.E., M.I.Mech.E., Engineer-in-Chief. The specification and Form of Tender may be inspected at the office of the Board, Embankment, E.C. 4., and can be obtained upon payment of a deposit of £1. The amount of the deposit will be returned only after the receipt of a *bona fide* Tender sent in accordance with the instructions on the Form of Tender and after the specification has been returned

Tenders, addressed as noted on the form, must be delivered at the Office of the Board not later than 2.30 p.m. on Wednesday, 29th March.

(By Order)
DUNCOMBE MANN,
Clerk to the Board. T 675

SWANSEA HARBOUR TRUST.

The Trustees invite

Tenders for the Supply and DELIVERY of the following:—
950 NEW CREOSOTED SLEEPERS, 9 ft. by 10 in. by 5 in.
Approximately 3300 cub. ft. 12 in. by 6 in. PITCH PINE CROSSING TIMBERS, in length varying from 9 ft. to 26 ft. A schedule of length will be supplied.
About 47 tons CAST IRON RAILWAY CHAIRS, approximately 44½ lb. each.
About 5 tons of 7/8 in. by ¾ in. and about 5 tons of 8/8 in. by ¾ in. FANG BOLTS with 3 in. Triangular Shoes.

Further particulars may be obtained of the Trustees' Engineer, Mr. A. O. SCHENK, M.I.C.E., Harbour Offices, Swansea.

Tenders, sealed and marked "Railway Material," to be delivered to the undersigned on or before 17th March, 1922.

The Trustees do not bind themselves to accept the lowest or any Tender.

TALFOURD STRICK,
Clerk.

Harbour Offices, Swansea.
March 1st, 1922. T 623

STATE ELECTRICITY COMMISSION OF VICTORIA.

TENDERS FOR PLANT.

Tenders are Hereby In- vited for the SUPPLY, DELIVERY, etc., of the following for the Morwell Power Scheme.

Copies of Tender Form and Specification will be available upon application to:—

AGENT-GENERAL FOR VICTORIA,
Melbourne Place,
Strand,
London, W.C. 2.

SPECIFICATION No. 200. 23,000 volt 3-core CABLE and ACCESSORIES.

CHARGE:—
£2 2s. for the first two copies of Specification and 10s. 6d. per copy thereafter. These charges will be returned on receipt of a *bona fide* Tender.

PRELIMINARY DEPOSIT:—
A preliminary deposit of 1 per cent. (not exceeding one hundred pounds—£100) is to be lodged with Tender.

The Specification may be inspected at the above mentioned Office.

The Commission does not bind itself to accept the lowest or any Tender.

Tenders on prescribed form, properly endorsed and addressed, must be delivered to the undersigned in Melbourne, not later than 20th April, 1922,

R. LIDDELOW,
Secretary.

State Electricity Commission of Victoria,
673, Bourke Street,
Melbourne,
Victoria,
AUSTRALIA. T 595

PUBLIC HEALTH ACT, 1875.

URBAN DISTRICT COUNCIL OF RUISLIP NORTHWOOD, MIDDLESEX.

SEWAGE WORKS EXTENSION.

TO SEWAGE WORKS CONTRACTORS.

The Urban District Council of Ruislip Northwood are prepared to receive

Tenders for Certain Supple- MENTARY WORKS for SEWAGE DISPOSAL to be carried out at the Council's Purification Works in the Parish of Ruislip.

The Works will consist generally of Sedimentation Tank, Bacteria Beds, Humus Tanks, all requisite pipe connections, sluice gates, valves, and other fitments.

Particulars, Bills of Quantities and Forms of Tender may be obtained and plans may be seen at the offices of the Consulting Engineers, HOWARD, HUMPHREYS AND SONS, 28, Victoria Street, Westminster, on the 13th to the 17th days of March between the hours of Ten a.m. and Four p.m.

Intending Contractors will be required to deposit a sum of Three Guineas prior to particulars being furnished, such sum being returned after the Council have come to a decision on the Tenders received and provided that the Contractor shall have sent in a *bona fide* Tender and shall not have withdrawn the same. The successful Tenderer will be required to execute a contract and bond, the draft of which may be seen at 28, Victoria Street, Westminster, aforesaid.

Tenders must be on the official forms, each tender in a sealed envelope together with a filled in Bill of Quantities and Schedule of Prices signed in the handwriting of the Tenderer or his authorised Agent.

Tenders must reach the undersigned not later than Nine a.m. on the 27th day of March, 1922.

The Council do not bind themselves to accept the lowest or any Tender.

The acceptance of a Tender will in any case be subject to the approval of the Ministry of Health to the loan required for the work.

Given under my hand this 1st day of March, 1922.

EDMUND R. ABBOTT,
Clerk to the Council.

Council Offices,
Northwood, Middlesex. T 643

EDINBURGH CORPORATION ELECTRICITY SUPPLY.

PORTOBELLO STATION.

The Lord Provost, Magistrates and Council invite

Tenders for the following WORK:—

SPECIFICATION No. 42. CONVERTING PLANT FOR LIGHTING AND TRACTION.

SPECIFICATION No. 43. D.C. SWITCHGEAR.

A copy of the Specification and accompanying Drawings can be obtained from SIR ALEXANDER B. W. KENNEDY, 17, Victoria Street, Westminster, S.W. 1, on and after Tuesday, 14th March, upon payment of a deposit of £2 2s. An additional copy of the Specification can be obtained upon payment of a deposit of £1 1s. These deposits will be returned after the receipt of a *bona fide* Tender, and on the return of the Specification and Drawings.

Tenders on the prescribed Form, enclosed in sealed envelopes, and addressed on the outside:—"Electricity Supply, Tender to Specification....," must be delivered at the office of the undersigned not later than Saturday, the 15th April 1922, at Ten a.m.

A. GRIERSON, S.S.C.,
Town Clerk,
City Chambers,
March, 1922. Edinburgh. T 660

LONDON COUNTY COUNCIL.

Tenders are Invited for the MANUFACTURE, SUPPLY, DELIVERY, and ERECTION at Greenwich Power Station of:—

(A) An ASH CONVEYOR of the water immersed, drag-link type.

(B) An ASH HOPPER.

The Specification, Form of Tender, and general conditions may be obtained from the Clerk of the Council, County Hall, Spring Gardens, S.W., upon payment to the Cashier of the Council of a deposit of £2. This amount will be returnable only if the Tenderer shall have sent in a *bona fide* Tender and shall not have withdrawn the same. Particulars of the work may be obtained on application at the County Hall before the payment of the fee.

Tenders must be addressed to the Clerk of the Council and delivered at the County Hall, Spring Gardens, S.W. 1, not later than Four p.m. on Monday, 10th April, 1922 No Tender received after that time will be considered.

The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk of the London County Council.
T 671

MANCHESTER CORPORATION WATERWORKS.

THIRLMERE AQUEDUCT: FOURTH PIPE LINE.

DISCHARGE VALVES, &c.

The Waterworks Committee invite

Tenders for the Supply of 6 in. DISCHARGE VALVES, MANHOLE DOORS, LADDERS, JOISTS, and other IRONWORK.

Specification, Form of Tender, &c., may be obtained on application to the Secretary, Waterworks Offices, Town Hall, Manchester, upon payment of a deposit of Three Guineas, which will only be returned to the tenderer provided that he shall have sent in a *bona fide* Tender and shall have returned the Documents and the Drawings lent to him, the Drawings to be unmarked. Further information, if required, may be obtained from the Waterworks Engineer.

Sealed Tenders, endorsed as directed, must be delivered at the Waterworks Offices, Town Hall, Manchester, not later than the 25th March, 1922.

By Order,
THOMAS HUDSON,
Town Clerk.

Town Hall, Manchester.
7th March, 1922. T 650

METROPOLITAN WATER BOARD.

WALTON TO HONOR OAK MAIN.

SECTION No. 3.

TENDER FOR THE LAYING OF A MAIN FROM CLAPHAM PARK TO PECKHAM RYE.

The Metropolitan Water Board invite

Tenders for the Laying and JOINTING of about 8400 LIN. YARDS of CAST IRON WATER MAIN 48, 42, and 36 in. in diameter from Thornton Road, Clapham Park, to the junction of Colyton Road, and Homestall Road, Peckham Rye, in the County of London, together with Contingent Works.

Drawings, Conditions of Contract, and Specification may be inspected without payment of fee at the Offices of the Board, Chief Engineer's Department (Room 201), on and after Monday, 13th March, 1922.

Forms of Tender, Conditions of Contract, Specification, Bills of Quantities, and Schedules of Prices, together with a spare copy of the Bills of Quantities and Schedules of Prices, may be obtained on and after 13th March, 1922, from Mr. HENRY H. STILGOE, M.Inst.C.E., the Chief Engineer, on production of an official receipt for the sum of £30, which sum must be deposited with the Accountant to the Board, and will be returned on receipt of a *bona fide* Tender, accompanied by all the above named documents (with the exception of the spare copy of the Bills of Quantities and Schedules of Prices, which may be retained by the Tenderer). Such payments and applications must be made between the hours of Ten a.m. and 4.30 p.m. (Saturdays Ten a.m. and Twelve noon).

Tenders enclosed in sealed envelopes addressed to "The Clerk of the Board, Metropolitan Water Board, New River Head, 173, Rosebery Avenue, Clerkenwell, E.C. 1," and endorsed "Tender for Main, Walton to Honor Oak, Section No. 3" must be delivered at the Offices of the Board not later than Ten a.m. on Monday, 10th April, 1922.

The Board do not bind themselves to accept the lowest or any Tender.

W. MOON,
Clerk of the Board.

Offices of the Board,
New River Head,
173, Rosebery Avenue,
Clerkenwell, E.C. 1.
4th March, 1922. T 656

THE HIGH COMMISSIONER FOR INDIA is prepared to receive

Tenders for the Supply of:—MACHINE for GRINDING LOCOMOTIVE CRANK PINS.

Forms of Tender may be obtained from the Director-General, India Store Department, Belvedere Road, Lambeth, S.E. 1, and Tenders are to be delivered at that Office not later than Two o'clock p.m., on Friday, the 24th March, 1922.

T. RYAN,
Director-General. T 632

SLIGO, LEITRIM & NORTHERN COUNTIES RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for 240 Tons of British Standard FLAT-BOTTOMED STEEL RAILS, 75 lb. per yard, with the necessary Fishplates, four holes in each rail. Length of rails to be 45 ft. with 7½ per cent. of shorts, no rail to be less than 30 ft. long.

Delivery into trucks—Belfast, Dundalk or Londonderry, not later than Saturday, 20th May, 1922.

Tenders to be addressed to SECRETARY, S.L. and N.C. Rly., Enniskillen.

The Directors do not bind themselves to accept the lowest or any Tender. T 674

BOROUGH OF CAMBERWELL.

TO ENGINEERS, BOILER MAKERS, &c.

The Council invite

Tenders and Schemes for One NEW WATER TUBE STEAM BOILER, TWO NEW STEAM CALORIFIERS, and other work in connection with the rearrangement of the Boiler House at the Public Baths, Church Street, Camberwell, S.E. 5.

Specification and Form of Tender can be obtained from Mr. FREDERICK J. SLATER, Borough Engineer, Town Hall, Camberwell, S.E. 5.

Tenders, together with complete Drawings and full particulars of proposed schemes, must be delivered on or before Thursday, 23rd March, 1922, not later than Five p.m.

C. WILLIAM TAGG, Town Clerk. T 673

METROPOLITAN BOROUGH OF ST. MARYLEBONE.

HIGHWAYS DEPARTMENT.

The Council of the Metropolitan Borough of St. Marylebone invite

Tenders for the Supply of CONVEYERS for Ashes and Breeze.

Further particulars and Forms of Tender may be obtained on application to the Highways Engineer to the Council.

Tenders to be delivered in sealed envelopes endorsed "Tender for Conveyers," and be addressed to the undersigned on or before Twelve noon on Monday, the 20th March.

The Council do not bind themselves to accept the lowest or any Tender.

By Order,
JAMES WILSON,
Town Clerk.

Town Hall,
Marylebone Road, N.W. 1. T 701

URBAN DISTRICT COUNCIL OF CHEADLE AND GATLEY.

ELECTRICITY SCHEME.

TENDERS FOR MAINS, ETC.

The Urban District Council of Cheadle and Gatley invite

Tenders for Extra High PRESSURE, MEDIUM PRESSURE and LOW PRESSURE MAINS and STREET LIGHTING ACCESSORIES. Copies of Specification with Form of Tender and General Conditions can be obtained of the Council's Engineer, Mr. C. H. WORDINGHAM, O.B.E., M.Inst.C.E., either from 11, Mosley Street, Manchester, or 7, Victoria Street, Westminster, London, S.W. 1. A complete set of the drawings referred to in the Specification can be seen between the hours of Ten a.m. and Four p.m. at the same addresses.

A deposit of Three Guineas in respect of the Specification is required, which sum will be refunded within one month of the date of the adjudication upon the Tenders, provided that a *bona fide* Tender be submitted and not withdrawn.

A duplicate copy of the Specification and General Conditions will be supplied on payment of One Guinea, which sum is not returnable. A complete set of drawings will be supplied on payment of the sum of One Guinea, which sum also is not returnable.

Tenders enclosed in an envelope sealed with wax and clearly endorsed "Tender for Mains, Cheadle," must be addressed to the undersigned, Clerk to the Urban District Council of Cheadle and Gatley, Council Offices, Cheadle, Cheshire, and must be delivered not later than Noon on the 3rd April, 1922.

The Council do not bind themselves to accept the lowest or any Tender.

By Order,
JOHN H. JOHNSON,
Clerk to the Council.

Council Offices,
Cheadle, Cheshire,
7th March, 1922. T 681

APPOINTMENTS OPEN.

CHIEF ELECTRICAL ENGINEER.

The Rangoon Electric TRAMWAY & SUPPLY COMPANY LIMITED REQUIRE THE SERVICES of a GENTLEMAN of first-class standing and good experience Alternating Current and Tramways, as CHIEF ELECTRICAL ENGINEER, for Rangoon. Five years' engagement.

Apply, by letter, stating age, salary required, full particulars of qualifications, experience and copies (only) of Testimonials, to the London Agents—Messrs. R. LAWRENCE SPICER & CO.,
3/4, Great Winchester Street,
London, E.C. 2. T 658

Wanted, Engineer thoroughly experienced in Aerial Ropeways, to take charge of Drawing Office. Also a LEADING DRAUGHTSMAN required. State full particulars, experience, salary, etc.—Address, T 562, Offices of ENGINEERING.

SOME PROPERTIES OF THE WORKING FLUID OF GAS ENGINES.

By W. T. DAVID, M.A., D.Sc., Professor of Engineering, University College, Cardiff.

AN attempt is made in this article to clear up certain obscure points in the working of gas engines, and to describe some of the properties of the working fluid which have been ascertained recently from experiments made by the author. Before passing on to detailed statement it will be convenient to summarise the main conclusions reached.

The article is divided into four sections. In the first section it is shown that incomplete combustion, increasing specific heat and cooling are all important factors in limiting the pressures developed during the explosion of mixtures of coal-gas and air contained in a closed vessel. Experiments show that only 90 per cent. of the coal-gas is burnt by the time the maximum pressure is reached, and it is estimated that were it possible to check all heat loss and burn all the gas within the explosion period the maximum rise of pressure would be increased by 14 per cent. in the case of a 15 per cent. mixture of coal-gas and air and by 31 per cent. in the case of a 9·7 per cent. mixture.

In the second section after-burning in a gas-engine cylinder is discussed. It is inferred that with normal ignition only about 70 per cent. of the fuel charge is burnt at the moment indicated by the peak of the indicator diagram, and there seems little doubt that incomplete combustion ranks equally with increasing specific heat as a primary cause limiting the maximum pressures developed in gas engines. The distinction between inflammation and combustion is emphasised, and it is suggested that with normal ignition setting the maximum pressure occurs more or less in the neighbourhood of complete inflammation. In strong mixtures which give vertical explosion lines in the indicator diagrams, the bulk of the after-burning appears to be completed in the early stages of the expansion stroke, owing to the fact that the rate of change of volume is small in this epoch. Consequently, in strong mixtures after-burning does not affect the thermal efficiency very much. In the case of weaker mixtures giving sloping explosion lines the rate of change of volume after the maximum pressure is reached becomes fairly rapid, and after-burning continues for some considerable distance down the expansion line. The thermal efficiency is therefore considerably affected both on account of slow inflammation and on account of after-burning. The conclusion is reached that the defect of the actual efficiency of an engine from the ideal variable specific heat efficiency is to be attributed mainly to heat flow from the working fluid into the cylinder walls when it is working on strong mixtures and mainly to slow inflammation and after-burning when it is working on weak mixtures. The possibility of speeding up after-burning is discussed and suggestions are put forward for a research directed to this end.

In the third section it is shown that the curve prepared by the British Association Committee on Gaseous Explosions connecting the internal energy of a typical gas engine mixture with its temperature requires modification at the higher temperatures. Assuming the correctness of the curve at the lower temperatures a modified curve has been prepared which gives at 2,000 deg. C. a value for the internal energy about 4 per cent. less than that given by the British Association Committee.

In the fourth section it is shown that the heat loss in any given engine working at a constant speed may be calculated approximately by means of the formula $K T^{2}_{max.}$, in which K is a constant for the given engine and $T_{max.}$ the absolute maximum temperature developed on explosion of the charge. It is also shown that, although the heat loss by conduction per unit area of wall surface at any given gas temperature is independent of the dimensions of the cylinder, the loss by radiation per unit area increases greatly with the dimensions. The reason for the unreliability of the large gas engine is thus made clear.

SECTION I.—PRESSURES DEVELOPED ON EXPLOSION.

It is well known that the maximum rise of pressure developed in a gas engine during the explosion of its charge is only about half that which would be produced if a quantity of heat equal to the heat of combustion of the charge were added to an equal volume of air. Careful measurements by Clerk, Mallard and Le Chatelier, Langen and others have shown this even under the ideal conditions obtainable in a closed vessel the observed pressures are less than 60 per cent. of the theoretical air pressures.

Causes Limiting the Pressures Developed.—The investigation of the causes responsible for the limiting of the pressures is one of the most interesting problems presented by the internal-combustion engine, and much work has been done in connection with it both in this country and on the Continent during the last forty years or so. The main theories which have been put forward are well known: they are the incomplete combustion theory (Clerk), the increasing specific heat theory (Mallard and Le Chatelier), the cooling theory (Hirn), and the dissociation theory.

It is generally agreed now that the amount of dissociation is likely to be small even at the highest gas-engine temperatures,* and its effect may be conveniently included under the head of increasing specific heat since it would naturally be included in all physical measurements of specific heat. The cooling theory has never been regarded as an adequate explanation of the observed pressures, but it is clear that cooling must play some part in limiting the pressures developed. Opinion has been divided mainly between the incomplete combustion theory and the increasing specific heat theory. The experiments of Holborn and Henning on the specific heat of CO_2 and water-vapour† and those of Clerk on the specific heat of a gas-engine mixture‡ have shown that the heat capacity of these gases does undoubtedly increase very considerably with the temperature. Much qualitative support was thus lent to the increasing specific heat theory and, judging by the mass of recent literature, writers of distinction, with the notable exception of Sir Dugald Clerk, have accepted this theory as being capable in itself of accounting for the observed pressures, and have abandoned the incomplete combustion theory.

The author has recently published an account of some of his experiments which he believes prove conclusively that incomplete combustion, increasing specific heat and cooling are all important factors in limiting the pressures developed, even under the ideal conditions of perfect mixing obtainable in a closed vessel.§ Acting originally on the suggestion of the late Professor Bertram Hopkinson, he made continuous measurements of the heat loss simultaneously with continuous pressure measurements during the explosion and subsequent cooling of mixtures of coal-gas and air contained in a cylindrical cast-iron vessel, 12 in. in diameter and 12 in. in length. From these measurements it was possible to form a quantitative estimate of the influence of each of these factors on the observed pressures.

The results for three different mixtures are embodied in Table I. The strongest mixture contained 15 per cent. of coal-gas and developed a maximum pressure of 120 lb. per square inch absolute (corresponding to a mean gas temperature of 2,170 deg. C.) in 0·05 second. The next mixture contained 12·4 per cent. of coal-gas and developed a maximum pressure of 105 lb. per square inch absolute (temperature 1,780 deg. C.) in 0·08 second. The weakest mixture containing 9·7 per cent. of coal-gas gave a maximum pressure of 88 lb. per square inch absolute (temperature, 1,390 deg. C.) in 0·18 second.

It will be seen from the table that about 10 per cent. of the coal-gas originally in the vessel appears to be unburnt in each mixture at the moment of maximum pressure. The maximum pressure would therefore appear to be reached under the ideal conditions obtainable in closed vessel experiments when about 90 per cent. of the coal-gas has been completely burnt. The heat lost to the walls of the explosion vessel up to this moment ranges from 9 per cent. of the heat of combustion in the strongest mixture, to 18 per cent. in the weakest mixture.* The proportion of the heat of combustion in the form of thermal energy at the moment of maximum pressure varies from 81 per cent. in the strongest mixture to about 72 per cent. in the weakest mixture. Had the gaseous mixture after combustion a constant specific heat equal to that of air at atmospheric temperature and the temperatures developed in the various mixtures remained the same as those actually observed, the proportion of the heat of combustion which would have been accounted for as thermal energy would only have been 57 per cent. in the case of each mixture. The differences between this figure and those shown in the second column of the table is a measure of the average increase of the specific heat over the temperature ranges corresponding to the various mixtures.†

TABLE I.—*Distribution of the Energy of Combustion of Coal-Gas and Air Mixtures at the Moment of Maximum Pressure.*

Mixture Strength.	Per Cent. of Energy of Combustion in the Form of Internal Thermal Energy of the Gaseous Mixture.	Per Cent. of Energy of Combustion in the Form of Available Chemical Energy.	Per Cent. of Energy of Combustion Lost to Walls of Explosion Vessel by Cooling.
per cent.			
15·0	81·0	10·0	9
12·4	78·0	12·0	10
9·7	72·5	9·5	18

The pressures shown in Table II have been calculated from the data given in Table I and the internal energy values given in Section III of this paper.

TABLE II.

Mixture Strength.	Actual Maximum Rise of Pressure.	Calculated Rise of Pressure if Heat Loss During the Explosion Period were Checked.	Calculated Rise of Pressure if Heat Loss were Checked and Combustion Completed During the Explosion Period.	Calculated Rise of Pressure if Gaseous Mixture had Constant Specific Heat Equal to that of Air at Ordinary Temperature (Heat Loss Checked and Combustion Completed).
per cent.	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per sq. in.
15·0	105	113	120	180
9·7	73	88	96	125

It will be seen from this table that if the heat loss during the explosion period could be prevented the rise of pressure would be increased by about 8 per cent. in the strong mixture and by 19 per cent. in the weak mixture. If heat loss were prevented and combustion completed during the explosion period the increases in the rise of pressure would be about 14 per cent. and 31 per cent., respectively, in the two mixtures. The theoretical air pressure rises are about 50 per cent. and 30 per cent. respectively greater than the pressure rises, assuming no heat loss and complete combustion.

Actual and calculated pressure curves to a time base for the 15 per cent. and the 9·7 per cent. mixtures are shown in Fig. 1, page 382. The A-curves show the actual pressures observed in the explosion vessel; the B-curves the pressures which would be developed were heat loss prevented and the C-curves the pressures which would be developed were heat loss prevented and combustion completed during the explosion period. The D-curves (dotted) show the theoretical air pressures under conditions of complete combustion within the explosion period and no heat loss. It will be noted that the B-curves approach the C-curves as combustion becomes

* The dissociation theory has recently been revived again by Messrs. Tizard and Pye in connection with petrol engine theory (*The Automobile Engineer*, February, 1921). In such engines, however, the temperatures are considerably higher than in gas engines.

† Wied. Ann. 23, 1907, page 809.

‡ Proc. Roy. Soc. A, vol. lxxvii, 1906, page 499, and Proceedings Inst.C.E., 26 February, 1907, page 15.

§ Proc. Roy. Soc. A, vol. xcviii, 1920, page 303.

* The greater relative heat loss in the weakest mixture is due to the fact that it has a much longer explosion period.

† Other experiments by the author indicate that the specific heat of gases like CO_2 and steam which emit radiation varies appreciably at high temperatures with density and volume as well as with temperature (see *Phil. Mag.*, May, 1920, page 551). For this and other reasons the relative influence of increasing specific heat, incomplete combustion and cooling will be somewhat different in vessels of other sizes and in mixtures of other densities.

complete. It is estimated that combustion is practically completed about a quarter of a second after the moment of maximum pressure. The rate of burning during this interval is not constant; it becomes less and less as cooling proceeds. About half of the 10 per cent. of gas remaining unburnt at the moment of maximum pressure appears to be burnt one-twentieth of a second later.

SECTION II.—AFTER-BURNING IN GAS ENGINES.

The "Combustion Factor."—It will be convenient to call the proportion of the heat of combustion of the fuel which has been converted into thermal energy by the time the maximum pressure is reached the "combustion factor." It is not possible to say in the present state of knowledge to what extent this factor varies with volume, density and temperature before firing, but various considerations lead to the conclusion that within the limits of density, volume and temperature usual in gas-engine practice any such variation will not be very large. Assuming this to be so it is considered that the combustion factor of 90 per cent. obtained in the closed vessel experiments is probably the maximum attainable in gas engines fitted with ordinary ignition systems.

It seems pretty clear that in engines working under normal conditions the combustion factor (referred to the peak of the indicator diagram) generally falls far short of the closed vessel value of 90 per cent. Take, for example, some experiments by Sir Dugald Clerk with an engine operated in such a way that the suction temperature could be accurately measured and the charge thoroughly mixed before firing.* The thermal energy added by the explosion of the charge in these experiments up to the moment of maximum pressure amounts to only about 65 per cent. of its heat of combustion. Allowing for a heat loss of 5 per cent. of the heat of combustion during explosion (probably a generous estimate), the combustion factor becomes about 70 per cent.†

Confirmation of this result is to be found in the experiments of Hopkinson with a 40-b.h.p. Crossley engine working upon coal-gas. Hopkinson, in his paper‡ gives indicator diagrams and the necessary data by means of which the combustion factor may be estimated when the engine is running on full load first with a strong mixture and then with a weak mixture. It appears to be very much the same in both cases, although the indicator diagrams are different in appearance.§ After allowing for a loss of heat during explosion of 5 per cent. of the heat of combustion it is estimated at from 68 per cent. to 69 per cent. at the point of maximum pressure.

With advanced ignition higher combustion factors may, of course, be reached,‖ but in view of the foregoing results it seems improbable that combustion factors greater than about 70 per cent. are realised in gas engines with normal ignition. There seems little doubt, therefore, that incomplete combustion ranks equally with increasing specific heat as a primary cause limiting the maximum pressures developed in gas engines; indeed, it is the more important of the two in engines working upon weak mixtures.

Effect of After-Burning upon Efficiency.—In order to understand the reason for the low combustion factors obtained in gas engines as compared with those realised in closed vessels, it is necessary to consider what happens during the explosion of a gaseous mixture, and in particular to distinguish between inflammation and complete combustion.

Consider first the process of explosion in a closed vessel. From the pressure records (see Fig. 1) it will be seen that the pressure rises slowly at first and then with increasing speed until a maximum rate of increase is attained, which remains constant until the point marked M (Fig. 1) is reached. Afterwards the rate of increase becomes less and less until the maximum pressure is developed and then the pressure begins to fall.

Fig. 1. EXPLOSIONS OF 15% & 9·7% MIXTURES OF COAL-GAS AND AIR.

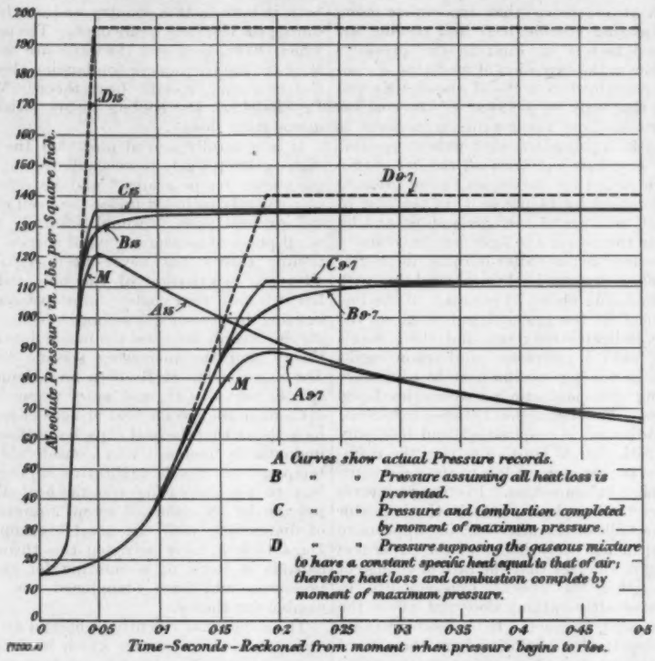
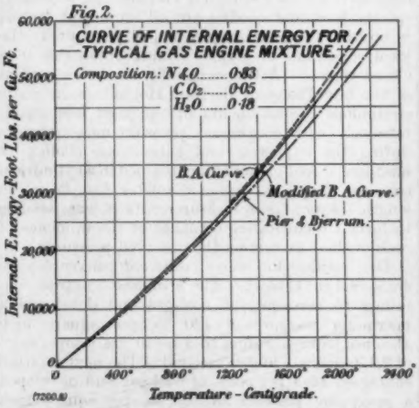

Absolute Pressure in Lbs. per Square Inch.
D15
C15
B15
M
A15
D9·7
C9·7
B9·7
M
A9·7
A Curves show actual Pressure records.
B " " Pressure assuming all heat loss is prevented.
C " " Pressure and Combustion completed by moment of maximum pressure.
D " " Pressure supposing the gaseous mixture to have a constant specific heat equal to that of air; therefore heat loss and combustion complete by moment of maximum pressure.
Time-Seconds-Reckoned from moment when pressure begins to rise.

Fig. 2.



It is now known that at or near the point M inflammation has spread completely through the gaseous mixture. At this moment about three-quarters of the gas appears to be burnt. The burning of the remaining quarter, which may be referred to as "after-burning"* takes rather more than a quarter of a second. At first it is sufficiently rapid to more than balance the cooling, and the pressure continues to rise, but later it becomes smaller and smaller and the cooling causes the pressure to decrease.

Various considerations lead the author to believe that in gas engines with normal ignition the maximum pressure (as indicated by the peak of the indicator diagram) occurs generally more or less in the neighbourhood of the moment of complete inflammation.* After-burning then continues during the expansion stroke. Generally the bulk of the after-burning in strong mixtures developing vertical explosion lines on the indicator diagram is probably effected in the early stages of the stroke, owing to the fact that the volume changes comparatively slowly in this epoch. Consequently its effect upon thermal efficiency is not great. The matter is different, however, in the case of weak mixtures giving sloping explosion lines. As the piston has travelled some distance forward by the time the maximum pressure is reached, the volume changes pretty rapidly immediately afterwards, and consequently after-burning continues for some distance down the expansion line. A considerable part of the defect of the actual efficiency in the case of an engine working on weak mixtures is thus to be attributed to after-burning.

The relative efficiency, that is, the ratio of the actual to the ideal efficiency may approach 90 per cent. in the case of an engine working upon strong mixtures, but it may be less than 80 per cent. in the case of weak mixtures. The defect of the actual efficiency from the ideal efficiency would appear in view of the foregoing observations to be due mainly to rapid heat flow into the cylinder walls in the case of strong mixtures and mainly to slow inflammation and after-burning in the case of weak mixtures.

Possibility of Speeding-up After-Burning.—It will be clear from the preceding section that the speeding-up of inflammation and of after-burning would result in considerably higher efficiencies in the case of gas engines working with weak mixtures. It is well known that the speeding-up of inflammation may be effected by increasing the turbulent motion of the charge before firing and also by stratification, and it need not, therefore, be discussed here. Attention will be confined in this section to the possibility of speeding-up after-burning, which is probably due to the constituent elements of the uncombined CO_2 and steam molecules failing to meet their partners except after undergoing a large number of collisions with other molecules.

The experiments of Professor H. B. Dixon suggest a possible method of effecting this. Dixon photographed the explosion flame travelling along a horizontal tube on a highly sensitive film rotated

* Clerk's experiments are described in detail in his Gustave Canet lecture to the Junior Institution of Engineers in 1913. An analysis of the exhaust gases in these experiments indicated that there was practically no unburnt fuel at the end of the expansion stroke.

† The maximum temperature developed was 1,380 deg. C. This occurs a little later than the maximum pressure (which corresponds to a temperature of 1,354 deg. C.) owing to the forward motion of the piston. Allowing for a heat loss up to the point of maximum temperature of 6 per cent. of the heat of combustion the combustion factor referred to this point is about 73 per cent. In estimating these combustion factors the internal energy values calculated in the manner shown in Section III have been employed.

‡ Proceedings Inst.Mech.E., 1908, page 404.

§ The explosion line in the diagram for the strong mixture is vertical and the peak is sharp; that in the diagram for the weak mixture slopes slightly, and the peak is rounded.

‖ The heat loss during explosion will, however, be greater with advanced ignition.

* It should be noted that the expression "after-burning" is here used to refer to the burning which takes place after the moment of complete inflammation. Hitherto it has been employed in referring to the burning which takes place after the maximum pressure has been reached.

* The moment of complete inflammation, it should be noted, marks the end of the period of the maximum rate of rise of pressure in the closed vessel.

in a vertical plane with a constant high velocity. His photographs indicate that the waves, which are set up during the development of the explosion in the tube, speed up combustion as they pass back and fore through that portion of the gaseous mixture which has undergone inflammation. Waves of the kind set up in Dixon's tube could probably be set up in a vessel approximating in shape to that of the combustion space in gas engines in various ways, but it cannot of course be predicted that the speeding up would be sufficiently great to affect the pressures developed materially. This can be decided only by experiment, and the author hopes to do some work on these lines as soon as research facilities have been developed in his laboratory.

SECTION III.—THE INTERNAL ENERGY OF THE WORKING FLUID.

A knowledge of the relationship between the internal energy, or the specific heat, of the working fluid and its temperature* is of primary importance from the point of view of gas-engine theory and design. Much labour has been expended in defining this relationship and the British Association Committee on Gaseous Explosions, after reviewing all the research which had been directed to this end, prepared a curve showing the internal energy of a typical gas-engine mixture for various temperatures up to 2,000 deg. C.†

From the author's experiments in which both heat loss and pressure measurements were made during the explosion and subsequent cooling of mixtures of coal-gas and air in a vessel of rather more than three-quarters cubic foot capacity, it is possible to deduce internal energy values for different gas temperatures. For reasons given in a previous paper‡ the absolute values of the internal energy so deduced may be subject to an error of the order of 5 per cent., but the variation of the internal energy with temperature after chemical and thermal equilibrium have been established is probably given with a good degree of accuracy. Accepting the values given by the British Association curve for temperatures below 1,200 deg. C., the experiments show that the values given by the curve for temperatures above 1,200 deg. C. are considerably too high. The reason for this is that the British Association curve at the higher temperatures is based upon Langen's explosion experiments in which an empirical correction was made for heat loss, but none for incomplete combustion. The curve as modified in the light of the author's experiments is shown in Fig. 2, page 382 (full-line curve). The original British Association curve is shown dotted so that the extent of the modification may be seen at a glance. At 2,000 deg. C. it amounts to about 4 per cent.

An examination of the modified curve shows that it is fairly accurately represented by the equation

$$E = 20\,t + 0{\cdot}00281\,t^2$$

where E is the internal energy (reckoned from 0 deg. C.) in foot-pounds per cubic foot at temperature t deg. C. The volumetric specific heat (in foot-pounds per cubic foot) at any temperature t is therefore given by

$$K_v = 20 + 0{\cdot}00562\,t^2$$

Recently the measurements by Pier and Bjerrum of the specific heats of nitrogen, carbon dioxide and steam up to temperatures of about 3,000 deg. C. have been made known in this country through Mr. D. R. Pye,§ and the chain-dotted curve in Fig. 2 gives the internal energy values deduced from their results for the typical gas engine mixture. It is represented by the equation

$$E = 18{\cdot}9\,t + 0{\cdot}00278\,t^2$$

This yields for the volumetric heat

$$K_v = 18{\cdot}9 + 0{\cdot}00556\,t$$

The internal energy values due to Pier and Bjerrum are pretty uniformly about 5 per cent. lower than those given by the modified British Association curve, and it is of interest to note that had these values been taken at the lower temperatures the author's curve would very nearly have coincided with the chain-dotted curve. In all calculations made in this paper the modified British Association values (corrected, of course, for varying composition of the mixtures) have been employed, as they yield results most disadvantageous to the theories advanced, but it is quite impossible to say in the present state of knowledge which of the two sets of values is the nearer to the truth.

Dr. W. J. Walker* has deduced the following equation from measurements upon indicator diagrams:

$$K_v = 18{\cdot}9 + 0{\cdot}005\,t$$

This gives values a good deal less than those deduced from the modified British Association curve and from the results of Pier and Bjerrum. Perhaps the discrepancy between the various results is to be explained in terms of the theory put forward by the author some time ago that the specific heat of a gas which emits radiation is dependent at high temperatures (700 deg. C. and over) upon volume and density as well as upon temperature.† This theory indicates that the specific heat at any given gas temperature increases (slightly in the neighbourhood of 1,000 deg. C., and markedly in the neighbourhood of 2,000 deg. C. and over) with the volume, but decreases as the density increases.

SECTION IV.—FACTORS GOVERNING HEAT LOSS DURING THE EXPLOSION-EXPANSION STROKE.

The effect of heat loss from the working fluid to the cylinder walls and piston upon the thermal efficiency has frequently been overrated in the past. It nevertheless exercises an appreciable influence upon efficiency, and it is estimated that were it possible to eliminate it altogether an engine working on strong mixtures with an actual efficiency of, say, 35 per cent., would yield an efficiency of about 40 per cent. It is, however, impossible to overrate its importance in connection with engine design. To it are due the costly cooling arrangements which add so greatly to the weight of the engine; and, indeed, it is the main factor limiting the development of large power units with single cylinders.

It is of the first importance, therefore, to obtain information relating to the factors governing heat flow from the working fluid. Much is already known. The experiments of Clerk and Hopkinson have made it clear that the rate of heat flow is vastly greater during explosion and the early stages of the expansion stroke than during the later stages of the stroke, and further, that the average heat flow during explosion and expansion in any given engine increases in a greater proportion than the mixture strength, upon which, of course, the temperatures developed depend. Both of these facts are highly important from the point of view of the designer. The former made it possible for Hopkinson to apply his system of internal cooling, from which great things were hoped and which, indeed, met with a considerable measure of experimental success. The latter made clear the great importance of working with as weak mixtures as is consistent with obtaining a reasonable amount of power in relation to the size of the engine.

Heat Loss Experiments in a Closed Vessel.—In order to gain further information in regard to heat loss the author undertook a series of measurements of the radiation loss and the conduction loss in a closed vessel, and investigated the dependence of each upon temperature. It is unnecessary to describe here the experimental methods adopted.‡ It will be sufficient to state that continuous records of the radiation loss and the conduction loss were separately made simultaneously with pressure records during the explosion and subsequent cooling of mixtures of coal-gas and air of various strengths contained in a cast-iron cylindrical vessel, 12 in. in diameter and 12 in. in length.

These experiments showed that the rate at which the gaseous mixture loses heat by radiation is proportional to the fourth power of its absolute temperature (T^4),* and that the rate of loss by conduction was approximately proportional to the fourth power of the temperature difference between the gaseous mixture and the walls $[(T - T_w)^4]$ for gas temperature above 2,000 deg. C absolute, and to the third power of this difference $[T-T_w)^3]$ for gas temperatures between 2,000 deg. C. absolute and 1,500 deg. C. absolute.† Over the temperature range 1,700 deg. C. absolute to 2,500 deg. C. absolute the rate of total heat loss (that is, the radiation plus the conduction loss) is sufficiently accurately given by an expression of the form $c\,T^4$, when c is a constant.

The conduction loss in the experimental vessel was found to be on the average about 50 per cent. greater than the radiation loss for mixtures of various strengths, but this holds only for an explosion vessel of the size used in these experiments. At any given gas temperature the rate of loss by conduction per unit area of wall surface is practically independent of the dimensions of the vessel, but further experiments have shown that the rate of loss by radiation per unit area of surface is very much dependent upon the vessel dimensions owing to the fact that the gaseous mixture is highly transparent to its own radiation. These experiments show that in a cylindrical vessel l in. in diameter and l in. in length the radiation loss per square inch of surface is proportional to $\sqrt{l}$.‡ The conduction loss over the entire surface is thus proportional to the surface, that is to l^2, and the radiation loss over the entire surface is proportional to the product of the surface and $\sqrt{l}$, that is to $l^{\frac{5}{2}}$.

Application of Results of Closed Vessel Experiments to the Gas Engine.—Two important results from the point of view of gas-engine design emerge from these experiments, neither of which, it may be noted in passing, could have been predicted from known physical laws. The first of these is the remarkable influence of temperature upon the heat loss from the working fluid both by conduction and by radiation, and the other is the dependence of the radiation loss per unit area of wall surface upon cylinder dimensions.

Influence of Temperature upon Heat Loss.—It will be remembered that the rate of total heat loss (that is, the radiation plus the conduction loss) at any gas temperature T in the closed vessel is given by the expression $c\,T^4$. It would involve very great labour, however, to apply an expression of this kind directly to the calculation of heat loss from the indicator diagram, and a further examination of the closed vessel results suggests the possibility of building up a simple expression which may be easily applied to the diagram. The total heat loss during a period of say, half a second from the moment of ignition is found to be very approximately proportional to the square of the absolute maximum temperature developed ($T^2_{max.}$), and it would seem, therefore, that a formula of the type $K\,T^n_{max.}$ should give reasonably reliable information in regard to the total heat loss during the explosion-expansion stroke, K being a constant for any given engine working at a constant speed and $T_{max.}$ the maximum absolute temperature developed, which varies, of course, with the strength of the charge. From data furnished by the experiments of Clerk, Coker and Scoble, Burstall and Walker§ n is found to vary between 2 and about 2·2, and for purposes of approximate calculation sufficiently accurate results are obtained by taking $n = 2$.

Effect of Cylinder Dimensions upon Heat Loss.—The fact that the radiation loss per unit area in the closed vessel experiments increases with the size of the vessel shows that the heat loss per unit area of wall surface increases with cylinder dimensions

* The internal energy appears to vary with the volume and density as well as with the temperature (see footnote, page 381, third column). The extent of this variation is not known, and is neglected in this section.

† See the First Report of the Committee.

‡ Proc. Roy. Soc. A, vol. xcviii, 1920, page 314.

§ *The Automobile Engineer*, February, 1920, page 57.

* Proceedings Inst. Mech. E., December, 1920, page 1247.

† *Phil. Mag.*, May, 1920, page 551.

‡ Full details will be found in the following papers: Phil. Trans. A, vol. ccxi, page 375; *Phil. Mag.*, September, 1920, page 318; and Proc. Roy. Soc. A, vol. xcviii, page 303.

* Phil. Trans. A, vol. ccxi, page 375.

† *Phil. Mag.*, September, 1920, page 318.

‡ The experiments only cover the limits $l = 6$ in. to $l = 24$ in., but it is thought that the square root law may be applied without serious error within the limits of cylinder dimensions common in gas engine practice (see *Phil Mag.*, January, 1920, page 77). It is estimated that in a vessel 28 in. in diameter and 28 in. in length the radiation loss would be equal to the conduction loss. In larger vessels the radiation loss would be greater than the conduction loss.

§ Dr. W. J. Walker has been good enough to amplify his published data for the purpose of evaluating n.

in the case of gas engines working under similar conditions of mixture, strength and speed. The heat loss per unit area in engines working under similar conditions may be calculated approximately from the equation

$$H = C + R\sqrt{d}$$

where C is the conduction loss per unit area and $R\sqrt{d}$ is the radiation loss per unit area in a cylinder of diameter d. Some idea of the way in which H varies with d in actual engines may be obtained from the closed vessel experiments if it is assumed that the ratio between the conduction and the radiation loss in any given vessel does not vary very much with the density. The ratio $\frac{C}{R\sqrt{d}}$ in the experimental vessel ($d = 12$ in.) is about 1·5 and in a vessel for which $d = 48$ in. this ratio would be about 0·75. From these figures it is easily calculated that the total heat loss per unit area is about 40 per cent. greater in a cylinder of 48 in. diameter than in one of 12 in. diameter. Assuming the same law it may be shown in a similar manner that the heat loss per unit area is about 50 per cent. greater in a cylinder of 60 in. diameter than in one of 12 in. diameter.

The cooling arrangements in gas engines are designed chiefly with the idea of reducing the temperature variation in the metal so as to avoid the setting up of undue stresses and of securing that local temperatures do not rise to a point sufficient to cause pre-ignition. Owing to the great thickness of metal and the difficulty of keeping the jacket water flowing effectively in every corner, the design of the cooling arrangements would be sufficiently difficult in large gas engines even though the heat loss per unit area were not greater than in small engines; but added to this is the fact brought out by these experiments that the heat loss per unit area increases with cylinder dimensions. The reason for the unreliability of the large gas engine is thus clearly seen, and the physical impossibility of designing very large engines working upon ordinary cycles will be obvious unless steps are taken to secure lower gas temperatures in the working cylinder.

THE NEW STREET VIADUCT AT DOVER.

(*Concluded from Page* 255.)

CONSIDERING next the construction of the arched viaduct, two lengths of this are illustrated in Figs. 26 to 38, Plate XV with our issue this week, and in the views reproduced in Figs. 45 and 46, annexed. The elevation and plan shown in Figs. 26 and 27 refer to the length of viaduct extending between the two bow-string girder bridges, respectively over the drainage works, and the Dover and Deal Railway. The length illustrated in Figs. 30 and 31 is that extending south-east from the latter bridge and terminating in the ramp between retaining walls which rises from the street level close to the Town station. The six spans of this latter part of the viaduct are illustrated in Figs. 30 to 35, Plate XV. For the greater part of its length this section is straight, but at the higher end begins to curve slightly. In this length the viaduct is carried between the several piers, on two main longitudinal beams and two external beams. The whole width is thus divided into three longitudinal sections, the beam centres being 15 ft. apart. At the higher end (to the left in Fig. 31) the curvature is obtained by displacing the external beams slightly laterally, the two central beams being run straight on from one end of this part of the structure to the other. The beams rest on reinforced columns, those for the central beams being 18 in. by 18 in., and those for the side beams 18 in. by 12 in. The spans in this part vary from 33 ft. 10 in. to 40 ft. The construction of the outside beams of the 40-ft. span is shown in Fig. 32. For these arched beams the reinforcement consists in the centre at the top of two ¾-in. long bars, and two 1-in. short bars (see Fig. 38). At the bottom the continuous arched bars are two in number, and 1⅜-in. in diameter, while two other curved 1⅜-in. bars reinforce the arch on the under side in the centre, and are deflected to the upper side at the piers. In the shorter spans there are two top bars, ⅝-in. diameter, and the bottom and curved bars are 1¼ in. Figs. 34 and 37 show the central beams for the 40-ft. span. These have a section of 12 in. by 2 ft. 2 in. below the 6-in. flooring; in this case the depth at the springing is not so great as in the outside beams. The reinforcement at the centre is increased to nine 1½-in. bars below, and three 1-in. and three 1¼-in. bars above. Figs. 35 and 36 show details of one of the central beams at the extreme right of Fig. 31, running out into the abutment wall and columns. Here the reinforcement is arranged in two systems only, as is the case with all the shorter spans (Fig. 32). In this particular pair of beams there are six bottom bars 1¼ in. in diameter, and two 1-in. and two 1¼-in. bars at the top, in the centre. At the extreme left (Fig. 31), the main central beams do not run directly into columns, the junction with the abutment wall being shown in Fig. 33. On account of the unequal distribution over these beams the reinforcement is increased as shown, so that there are eight bars at the bottom in the centre. The secondary beams are spaced about 3 ft. 4 in. apart, and are 7 in. wide, extending 14 in. below the floor. The reinforcing is shown in Fig. 29, the top bars being ⅞-in., and the bottom two 1 in. The decking in the centre is 6 in. thick, with ½-in. and ⅞-in. reinforcement, while for the side paths the decking is 3 in. thick, with ½-in. reinforcing bars at 6-in. spacing.

The section shown in Figs. 26 and 27, between the two bridges, is mainly curved to a radius of 404 ft. 6 in. The spans shown in Fig. 26 are those measured on the longitudinal centre line. The detail, Fig. 28, shows one of the central beams at the extreme left of Fig. 26, where the arched viaduct ends in the bridge abutment. Fig. 28 shows how the beam runs out into a cross beam 2 ft. 10 in. deep, extending between the columns in the abutment wall at this point. This is similar to the construction shown in Fig. 33, and in fact applies to all cases in which the central beams join bridge abutments, excepting the beams B_2, Figs. 31 and 35. As regards other details this length of the viaduct resembles that already described. The views given in Figs. 45 and 46 are taken under the viaduct, the photograph reproduced in Fig. 46

THE NEW STREET VIADUCT AT DOVER.

CONSTRUCTED TO THE DESIGN OF MESSRS. L. G. MOUCHEL AND PARTNERS, LIMITED.

FIG. 45. VIEW UNDER VIADUCT ARCHES.

FIG. 46. JUNCTION OF VIADUCT AND SPUR.

THE NEW STREET VIADUCT AT DOVER.

CONSTRUCTED TO THE DESIGN OF MESSRS. L. G. MOUCHEL AND PARTNERS, LIMITED, ENGINEERS, WESTMINSTER.

(For Description, see Page 284.)

Fig. 26.

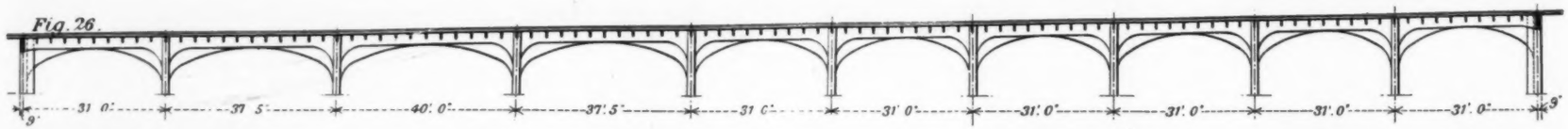


Fig. 28. SECTION B B.

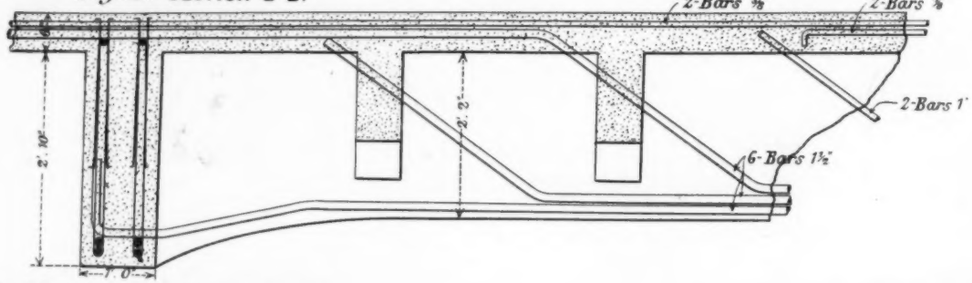


Fig. 29. SECTION C.C.

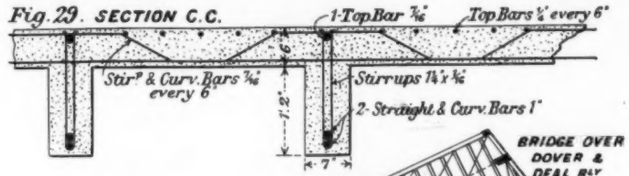


Fig. 27. PLAN (VIEW FROM BENEATH.)

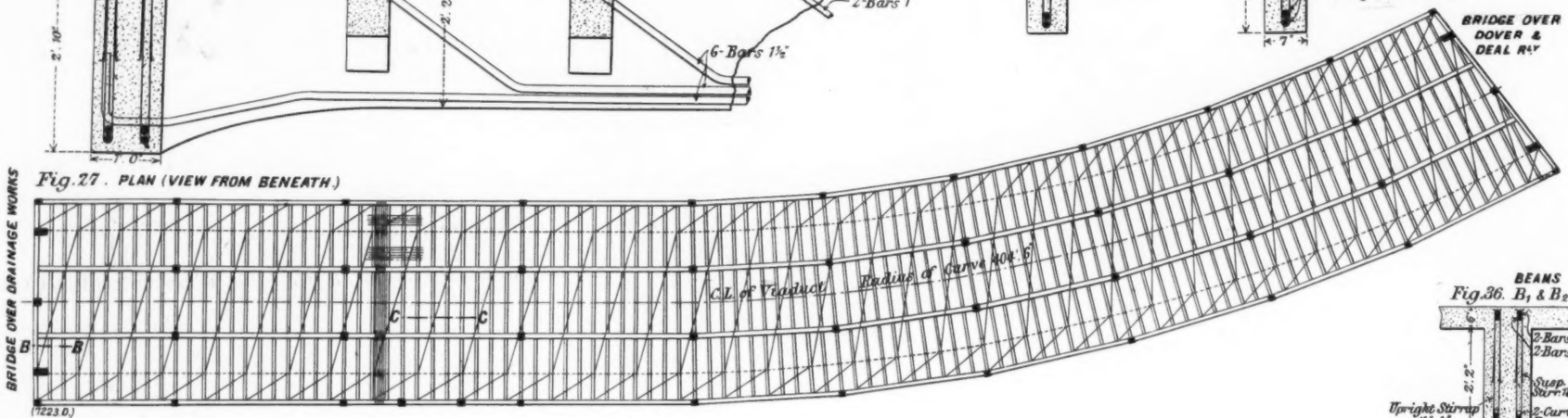


Fig. 30. VIADUCT OVER COUNCIL HOUSE STREET

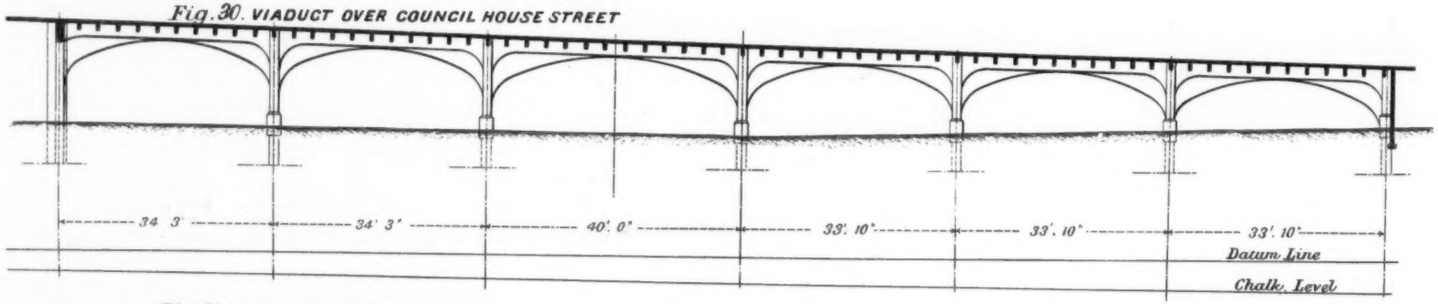


Fig. 31. PLAN (VIEW FROM BENEATH).

BEAMS

Fig. 36. B_1 & B_2.

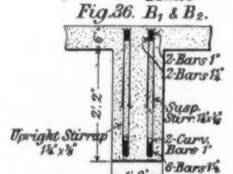


Fig. 37. C. BEAM

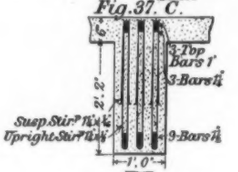
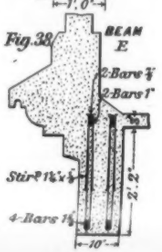


Fig. 38. BEAM E



THRO END WALL

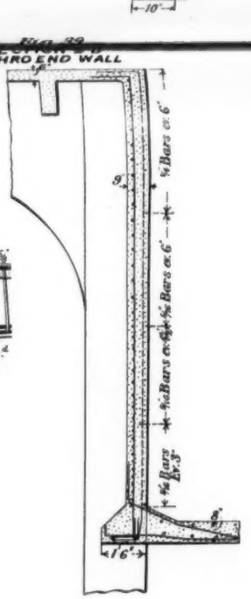


Fig. 32. DETAIL OF EXTERNAL BEAMS

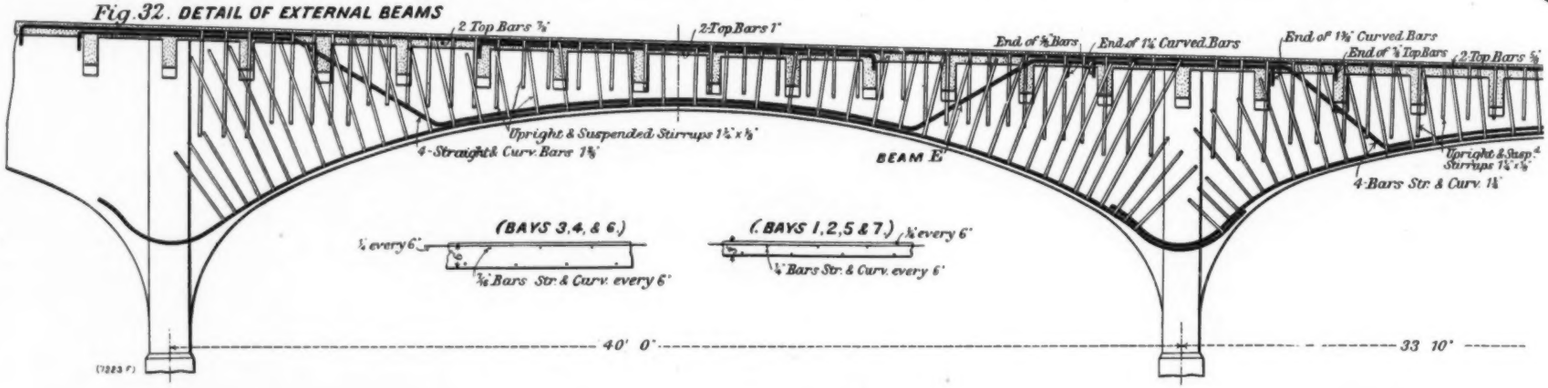

2 Top Bars ⅞"
2 Top Bars 1"
End of ⅞" Bars
End of 1¼" Curved Bars
End of 1½" Curved Bars
End of ⅞" Top Bars
2 Top Bars ⅝"
Upright & Suspended Stirrups 1½" x ⅜"
4 Straight & Curv. Bars 1⅛"
BEAM E
Upright & Susp.d Stirrups 1¼" x ⅜"
4 Bars Str. & Curv. 1¼"
(BAYS 3,4, & 6.)
¼ every 6"
⅞ Bars Str. & Curv. every 6"
(BAYS 1,2,5 & 7.)
¾ every 6"
⅞ Bars Str. & Curv. every 6"
40' 0"
33' 10"

Fig. 33. BEAM B_1.

Fig. 34. BEAM C.

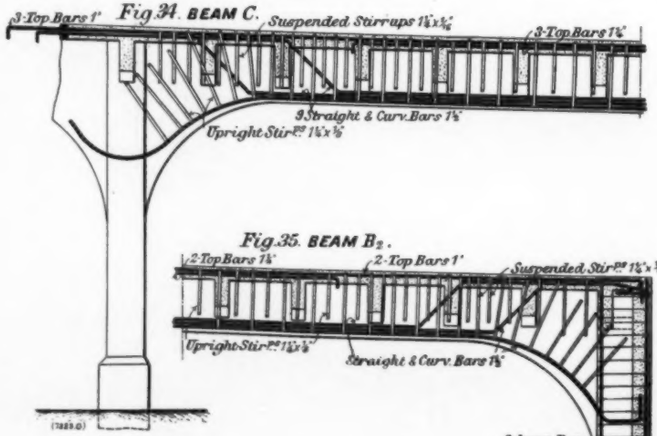


Fig. 35. BEAM B_2.

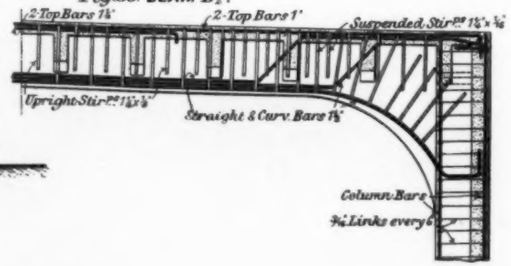


Fig. 40. SECTION A, A_1

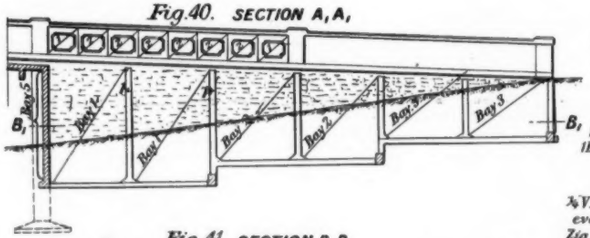


Fig. 41. SECTION B, B_1

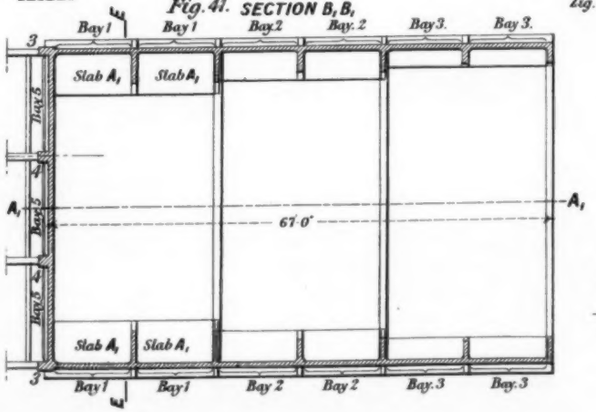


Fig. 42.
SECTION E-E
RETAINING WALL

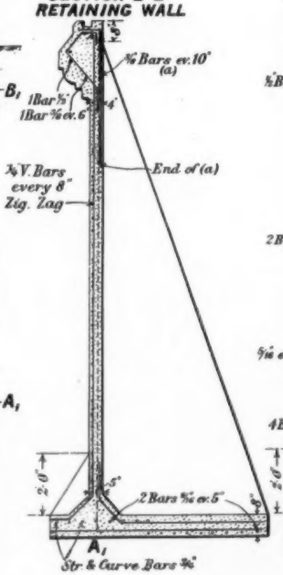


Fig. 43.

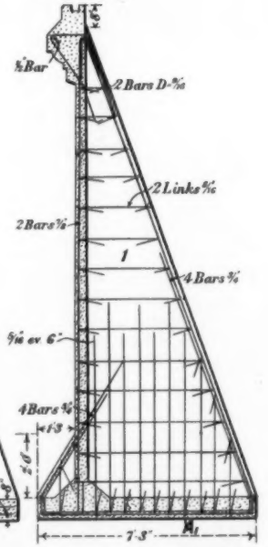
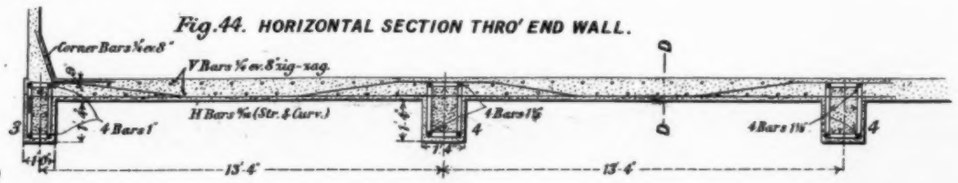


Fig. 44. HORIZONTAL SECTION THRO' END WALL.



THE NEW STREET VIADUCT AT DOVER.

CONSTRUCTED TO THE DESIGN OF MESSRS. L. G. MOUCHEL AND PARTNERS, LIMITED.

FIG. 47. VIADUCT APPROACH NEAR THE TOWN STATION.

being taken at the junction of the viaduct and spur.

Following the method adopted in connection with the bow string girder bridges, we will now deal with the tests conducted on the arch spans, taking first the tests on one of the 40 ft. spans. The details of the main central and side longitudinal beams for this 40-ft. span are given in Figs. 32, 34, 37 and 38. The most severe test was two trains consisting each of a 14-ton tractor and 12½-ton trailers. Only one trailer could be got on the span behind each tractor, so that the load amounted to 53 tons with the two trains, and this came mainly over the central longitudinal arch beams (Fig. 34). The maximum deflections recorded at the middle of these beams amounted to $\frac{1}{4,800}$ and $\frac{1}{5,840}$ of the spans respectively. Other tests were made on the 40-ft. span at the junction of the viaduct and the spur, including a static load test of 71 tons 4¾ cwt., concentrated on an area 15 ft. wide over one of the central beams, and extending over a strip 3 ft. 4 in. wide over a cantilever on each side. This allowed 10 tons 6 cwt. for road metalling, plus a test load of 210 lb. per square foot. The worst deflection at the point of the central longitudinal under the middle of the load was $\frac{1}{9,440}$ of the span, all other measurements showing smaller figures. The view reproduced in Fig. 25, page 254 *ante*, shows how the instruments were independently supported during these tests, the wooden indicator rods transmitting the deflection to them from the structure overhead. In another test, at this same point, a static load of 50 tons on one longitudinal beam was combined with a rolling load of 26½ tons passing over the other beam, the deflection being of the same order as that last mentioned.

As typical of tests on the shorter spans, we may refer to one on the 33-ft. 10-in. span, nearest the retaining wall approach at the Town Station end. The full test in this case was arranged with a static load of 24 tons, distributed over an area of 254 sq. ft., which extended the length of the span from one side longitudinal beam out a distance of 7 ft. 6 in. over the decking. As close to this load as possible were placed two 14-ton tractors side by side, each with a 12½-ton trailer behind it. The effect of this arrangement was to concentrate the whole of the load on a space two-thirds of the width of the viaduct. Deflection was taken at the centre of the central longitudinal beams, and of the side longitudinal under load, and also at the centre of the middle secondary beam in the side bay. The deflection in the latter case amounted to no more than $\frac{1}{11,420}$ of the span, and the worst deflection of the longitudinals, naturally that of the beam in the middle of the loaded two-thirds, amounted to only $\frac{1}{8,960}$ of the span, the allowable deflection according to the specification being $\frac{1}{600}$th of the span. Further tests were made on spans of 31 ft., to which we need not refer in detail. The results were equally satisfactory, and after the whole series were completed, Messrs. D. Balfour and Son reported that the structure had "in every way most satisfactorily withstood the tests applied, and that in no case had the allowable deflections been exceeded or even approached."

It should be noticed that the concrete work was completed, but no road metalling laid at the time of the tests. The wheel loads, therefore, came direct upon the concrete, with a consequent concentration of load, which would be much more severe on the work than if a layer of metalling had intervened, with its resultant spreading effect. The exhaustive tests are interesting, as they are made on a structure in which the design was not hampered by onerous public regulations, many of which would have involved far heavier scantlings than these tests show to be necessary.

Coming finally to the design of the retaining wall sections, although the two retaining wall sections of the viaduct are not identical, they are sufficiently similar for it to be unnecessary to deal in detail with more than one. That of which particulars are given in Figs. 39 and 44, Plate XV, is the arrangement adopted at the lower end of the spur, and leading into Bulwark-street; but the view given in Fig. 47, above, shows the approach near the Town station. The retaining wall is shown in elevation in Fig. 40, and in plan, Fig. 41, Plate XV. The abutment wall at the end adjoining the first span is 9 in. thick, and embodies four columns to take the main beams. These columns are 12 in. by 25 in., and 16 in. by 25 in., as indicated in Fig. 44, which gives a section of this wall. A vertical section through the end wall is given in Fig. 39. The side walls are 5 in. thick at the bottom, tapering to 4 in. at the top, with ½-in. vertical reinforcement every 8 in., and ⅞ in. horizontal reinforcement spaced 5 in. apart for the lower part, 5½ in. apart for the middle portion, and 10 in. apart for the upper section of the wall. The side walls have a small toe extending 15 in. on the outside (Fig. 42), and a much larger one on the inside to take sufficient load to prevent risk of overturning. The latter flooring extends inwards to various distances, as shown in Fig. 41, according to the height of the wall. The wall is cut up into sections, with inside counterforts tying together the wall and the floor. These are 8 in. thick, and the reinforcement for a typical one (actually one of the tallest) is shown in Fig. 43. In addition, at two intermediate points and one end ties extend across from wall to wall at the lowest level. These are rectangular in section and measure 12 in. by 18 in. They are reinforced by four ⅞-in. bars. The view shown in Fig. 47 annexed gives a very good idea of this part of the structure before the filling in process was commenced.

NOTES ON NEW BOOKS.

Italian technical literature has received a notable contribution in the shape of four volumes dealing with Engine Construction, by Professor Ottorino Pomini, of Milan University, who, at the same time is engineer to the well-known firm of Luigi Pomini, Castellanza. This work is the second edition of his "*Costruzione di Macchine*," Vol. I, dealing with Elasticity and the Resistance of Materials; Vol. II with Rotary Engine parts; Vol. III with Reciprocating Engines and their component parts; and Vol. IV with Toothed Wheel Gearing and other methods of transmission. The four books are most carefully printed and illustrated, and will prove of great service to Italian engineering students. They are issued by the publishing firm Ulrico Hoepli, Milan, at the price of 42, 16, 42 and 28 lire respectively.

A new technical dictionary in several languages is always an attractive publication to all writers whose business it is to render into their own language any description or specification issued in a foreign tongue, and the number of such writers is increasing every day. Lieutenant G. Malgorn, of the French Navy, "having felt the need of a recent work of this class for technical translations from the English, and being unable to find any, decided to edit one himself." His book is entitled "*Lexique Technique Anglais-Français*," and has been compiled in collaboration with Mr. Desmarets, chemical engineer. A glance through this shows that it has been prepared with great care; it measures 7½ in. by 5 in., and covers about 240 pages, including a number of conversion tables. The book is clearly printed, all English words being in heavier type; we hope it will have for one result to greatly facilitate business relations with our French friends. A misprint occurs in Table XIII, where 28 deg. F. should read 2·22 deg. C., and in Table XIV, where 4*s.* should read 5 francs, reckoning on the normal exchange which, we sincerely hope, will soon be restored. The dictionary is published at the price of 10 francs, by Messrs. Gauthier-Villars and Co., 55, Quai des Grands-Augustins, Paris.

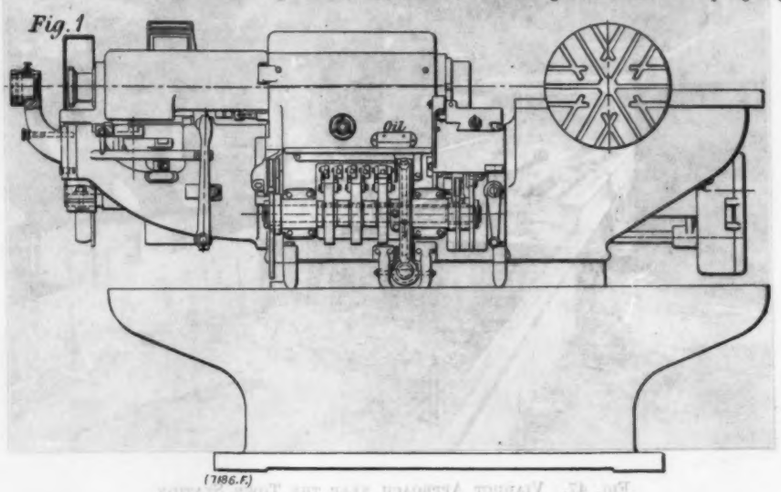
For certain purposes, such as for instance imparting knowledge to those more practically than studiously inclined, the method of question and answer is successful where the more thorough methods of carefully argued statements would in many cases fail. Moreover, when examinations, written and verbal are in view, whatever other methods may be chiefly relied upon, the question and answer system must be used to some extent in preparation for the test. As a means of marine propulsion the Diesel engine is rapidly gaining ground, and an increasing number of engineers are gathering sufficient practical experience to warrant them in going forward for the Board of Trade examinations for Diesel certificates. For the benefit of such there has been issued by Messrs. Griffin and Co., at 5*s.* net, a little book entitled "*Questions and Answers relating to Diesel, Semi-Diesel and other Internal-Combustion Engines, Air Compressors, &c.*," by John Lamb, M.I.Mar.E. It will no doubt be of assistance, although as rightly stated by the author, simple questions and answers cannot possibly cover the field. This is clearly indicated by some of the questions, which are quite incapable of any brief concise answer, the subject still largely being an open one. In other cases it would be more accurate to state limits rather than to give one figure applicable to some only of the many systems of Diesel engines at present in vogue. A few errors have crept in, but these in the next edition will no doubt be corrected. Of particular merit is the last section of the book, "Recent Examination Questions with Suggested Answers." The expositions here are very clear, and when additions are being made, these might well be taken as the standard at which to aim.

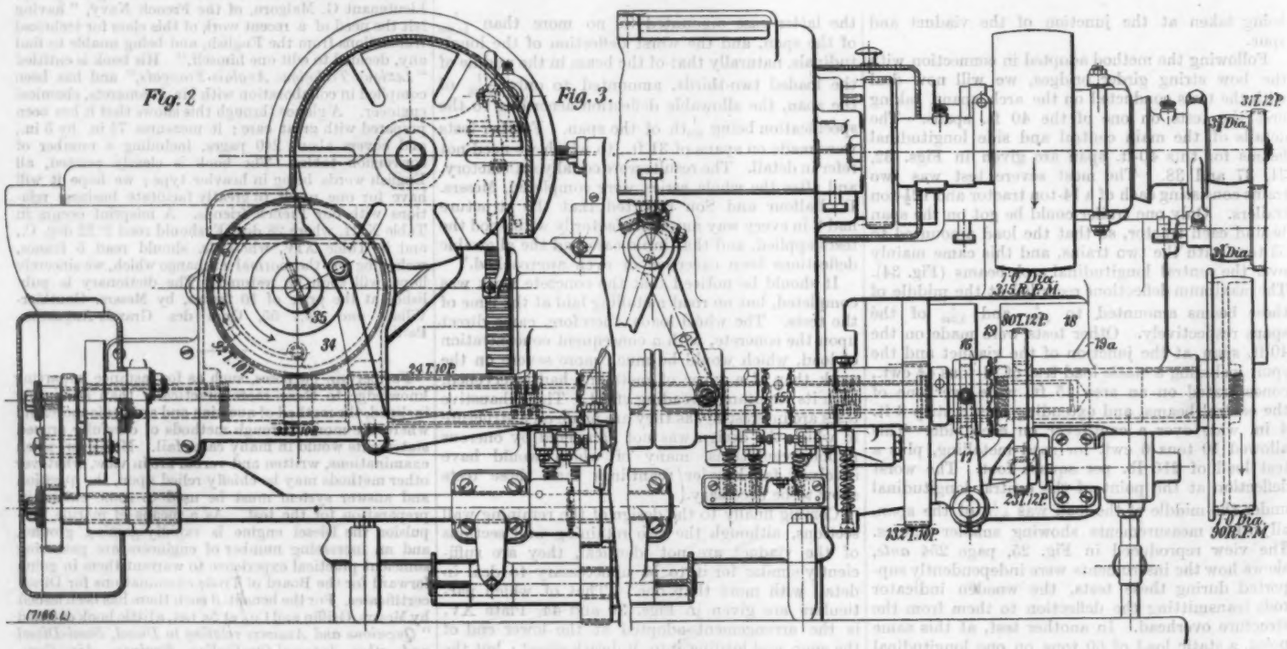
THE INSTITUTION OF ELECTRICAL ENGINEERS.—A new list of members of this Institution has just been published. Members desirous of having a copy can obtain one on application to the Secretary.

2-IN. AUTOMATIC SCREW MACHINE.

THE automatic screw machines of the smaller types made by Messrs. Brown and Sharpe of Providence, Rhode Island, U.S.A., are well known in this country, but the machine classed by these builders as their No. 6 is a larger size which differs considerably from the others and embodies many interesting features which will be unfamiliar to the users of the smaller machines. We illustrate this No. 6 automatic in Figs. 1 to 12, on the present page, and pages 288 and 289. The agents for Messrs. Brown and Sharpe's machines, &c., in this country are Messrs. Buck and Hickman, Ltd., Whitechapel-road, E.1. Of our illustrations Fig. 1, annexed, and Fig. 9, page 289, give respectively a line drawing and a general view of the front elevation of the machine. Fig. 10 gives a view of the back of the machine, a portion of which is again shown to a larger scale, with the shields removed, in Fig. 12. Fig. 2 and Fig. 3 are also drawings of portions of the back elevation of the machine. The headstock is shown in Fig. 4 and Fig. 11, pages 287 and 289, respectively, while a cross-section is given in Fig. 8. Fig. 5 and Fig. 6 show the arrangement of trip levers and cams, and the turret movement. Before entering upon a detailed description of the machine it will give some idea of its capabilities when we state that the largest size stock it will work is 2⅜ in. in diameter, turning any up to 5 in., and feeding any length up to 6 in. The number of pieces turned out per hour ranges between 3 and 180.

Commencing with the headstock and spindle drive, no countershaft is necessary. The single pulley is either driven by belt from line shaft over head, or by electric motor, in which case the position of the motor may be arranged on the floor or elsewhere to suit. It may be noted that the machines shown in Fig. 9 and Fig. 10 are not quite identical as regards one end, but Fig. 10 with the drawing (Fig. 1) represent the most complete model and our description will refer to details





as they appear in these latter illustrations. Referring to Fig. 4, page 287 of the headstock, it will be seen that the belt pulley which is 12 in. in diameter, taking a 4-in. belt, runs constantly. The speed is 315 r.p.m. and the drive is engaged by the clutch directly to the left of it, by the long lever, which in Figs. 4, 9 and 11 will be seen projecting towards the front over the headstock at the left end of the machine. This clutch transmits the drive to the pulley shaft, which carries at its right-hand end a gear engaging with a corresponding gear on this first shaft of the speed-box. These gears are capable of being changed, and wheels for 14 changes, ranging between spindle speeds of 48 r.p.m. to 875 r.p.m., are provided. The speed-box itself furnishes two speeds in either direction for each setting of the change gears. The speed box embodies two double clutches and two chain drives as may be seen from the view Fig. 11. The clutches A and B provide the two speeds, while C and D give the forward and reverse drives to the spindle. Supposing the clutches A and C to be engaged the drive to the spindle is through the gears 1 and 2 and the chain sprockets 3 and 8. If the clutches A and D are engaged the drive is through gears 1, 2, 4 and 5, and the chain sprockets 6 and 7. If B and C are engaged the drive is transmitted to the spindle through 5 and 4 and the chain sprockets 3 and 8; while if B and D are clutched in the drive is direct by the sprockets 6 and 7. The ratio of these speed changes is 3 : 1 in the same direction, and in opposite directions the ratio of fastest to slowest is 5 : 1. These clutches are operated by two levers visible at the back of the machine in Figs. 11 and 12, and mounted on the same axis. The movement of these levers is automatic, but before this can be explained we must refer to certain other parts of the machine. It will be well, however, first to complete the description of the headstock and spindle. The latter we have seen is driven either through the clutch C or the clutch D. The spindle terminates at the right end with a cap with a conical internal central seating. Against this seat is pressed the coned end of a split collet, 9. This collet will also be seen to taper towards the opposite end, and it fits into a tapered sleeve. It will be evident that if this taper sleeve is forced to the right the split collet will close on to the stock bar inside, though the collet itself has no end movement. The sleeve is given the necessary movement for the grip to be exerted, by a long tube and a short sleeve which are pressed forward by levers, 10, carried by the main spindle body. These levers are fulcrummed on the revolving piece, 11. They are fitted at the left-hand end with rollers, and over these latter the revolving ring, 12, is moved longitudinally by means of a lever fitted with a socket for a small bar and recognisable in Figs. 4 and 11. This lever is also worked automatically. If moved to the left the levers, 10, are forced in, an endwise movement to the right is transmitted to the sleeve, and the stock is gripped. If the lever moves the ring, 12, to the right the levers are released and the grip on the stock is relaxed. The lever operating the revolving ring, 12, is fitted with jaws provided with rollers.

The stock bar is held in a tube within the spindle and fitted at the right-hand end with spring fingers which exert sufficient hold on the bar to move it when the chuck collet is released. The tube slides in the sleeve, and at the left is fitted with a grooved collar over which fits a latch, 13, held in a sliding bracket, 14, well shown in Fig. 11. When the latch is engaged the bracket and tubes slide to and fro together. When the latch is raised the tube can be withdrawn from the spindle completely. The movement of the bracket is obtained from a horizontal grooved lever pivotted near the front of the machine. The pivotted end of this is to be seen at the bottom left-hand of Fig. 11. The far end is fitted with a roller and is moved to and fro in the slot of a cam drum driven from a shaft at the back of the machine. This cam drum may be seen at, 18, in Fig. 3, to which we shall refer in greater detail later. In order to secure the necessary latitude as regards length of feed the bracket is fitted with a block which fits into the groove of the lever operated by the cam drum. This block can be screwed to or from the lever pivot in order to adjust the stroke of the bar feed, by the small crank handle seen below the

bracket and slide in Fig. 11. The slide is graduated as shown in Fig. 4, and the stroke can be read off at once. The whole action of this feed is automatic. While the chuck still exerts a grip on the stock the bracket is drawn back by the cam and lever for the stroke required by the job. The chuck is then released and the cam and lever push the tube and bar forward, when the chuck is tightened again. Both actions, i.e., control of the chuck grip and the bar feed, are derived from levers working in separate grooves on the cam drum, 18, already referred to. The arrangement is similar to that of some of the smaller machines though the parts are disposed rather differently.

Both collet and spring fingers are provided with removable pads so that pads of a size required by the stock to be worked can be quickly fitted. By means of an outside feeding arrangement, when the inner feeder tube is removed, the size of stock worked may be increased to 2¼ in., the actual hole through the spindle being 2¼ in. in diameter. The main spindle has a conical bearing at the front (right) end, and a parallel roller bearing at the back end, a ball thrust bearing being also fitted at this point. The chain sprockets, 7 and 8, and the sleeve carrying 2, 3 and 4, are mounted on roller bearings. The whole of the headstock drive is enclosed and works in an oil bath, while a disc on the spindle fitted with pipes keeps lifting oil from the trough of the bath to the bearings.

Fig. 4.

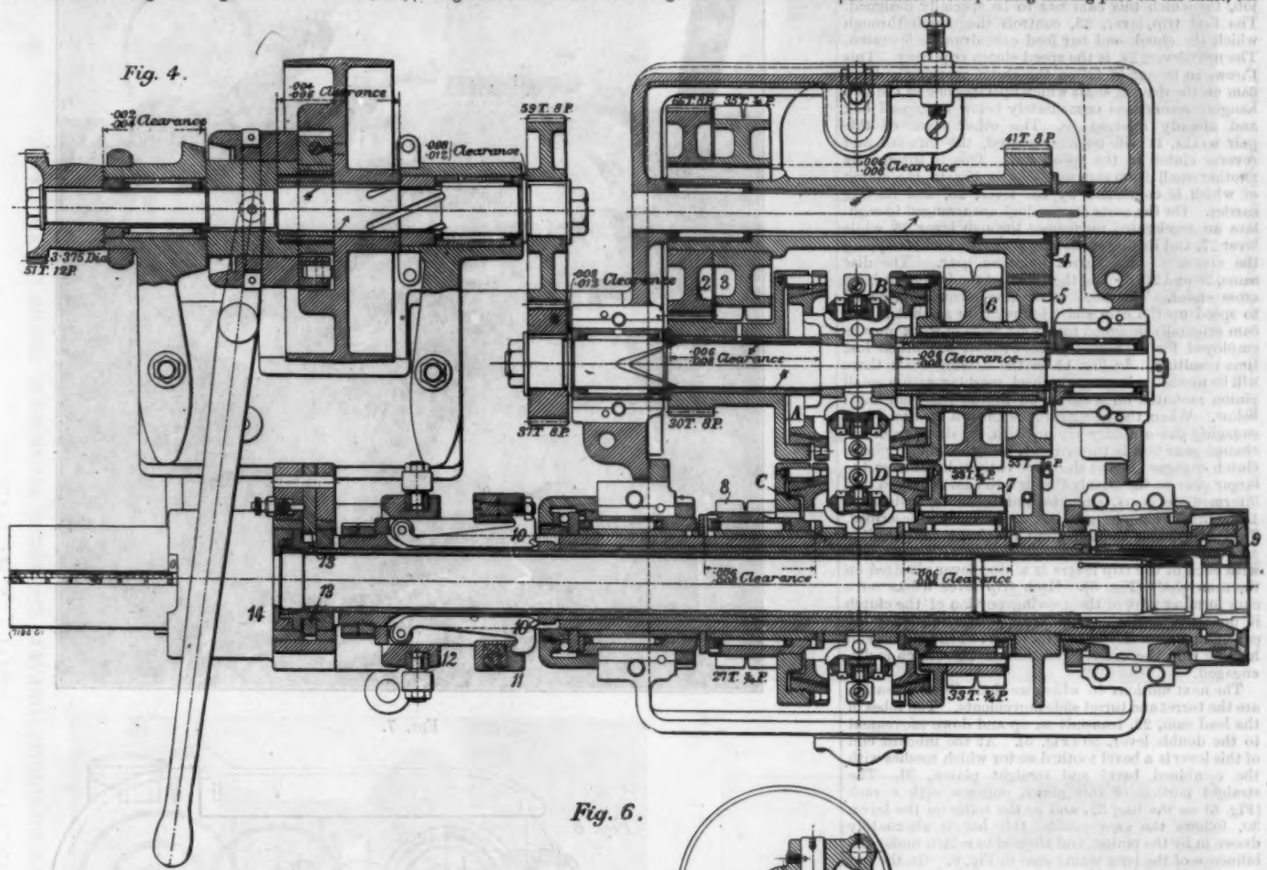


Fig. 5.

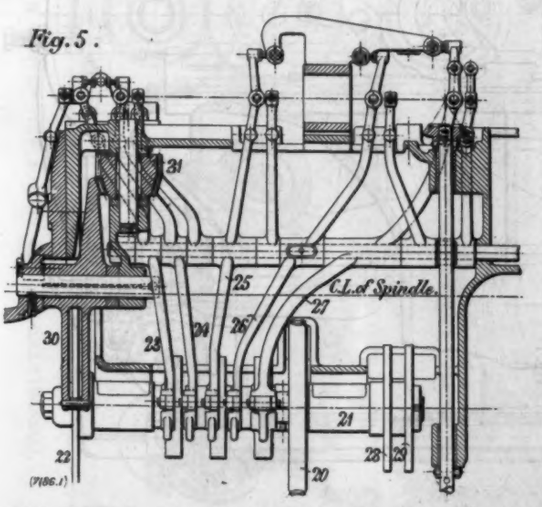
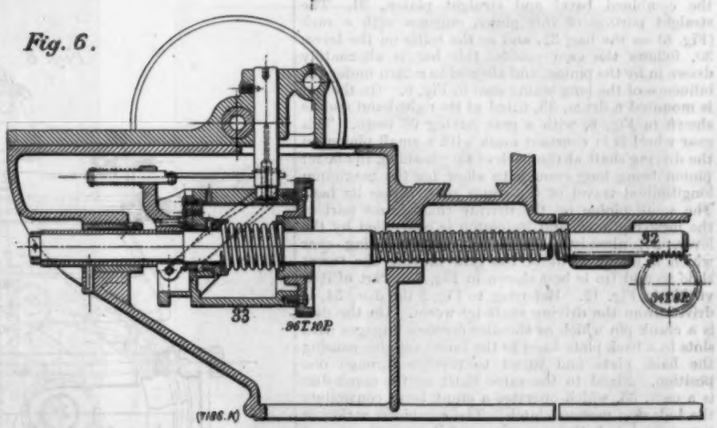


Fig. 6.



have seen, is independently driven, and if the clutches in the speed box and the main clutch are engaged, will continue to revolve. The combined bar feed and chuck grip cam drum, 18, to which reference has been made above, is driven from the main driving shaft, 15. Somewhat to the left of the lever, 17, is a small gear on a sliding clutch sleeve. When this sleeve is clutched in with its corresponding driving part on the shaft, the small gear is revolved and in turn drives a larger gear formed on the end of the combined bar feed and chuck grip cam drum, 18. On this drum the cam slots for these two movements can be seen at 19 and 19a (Fig. 3).

At the back of the machine are three horizontal shafts (Fig. 12). The uppermost of these three runs the whole length of the machine, and is driven through a clutch from the left-hand end of the machine by belt from the small pulley on the end of the constant speed pulley shaft (Figs. 3 and 10). This shaft is known as the driving shaft and is shown at 15, Fig. 3. It is run at constant speed; but by means of a jockey pulley and crossed main belt the fast movements of the machine can be converted to the slow ones with the contrary for the slow ones. On the driving shaft are dog clutches which operate practically all the automatic movements of the machine. The main clutch for the driving shaft is marked 16 (Fig. 3). This is operated by the lever, 17, which moves in response to the vertical hand lever in front of the machine to the left (Fig. 1). When this clutch is engaged the driving shaft revolves, but when it is disengaged by the hand lever control the whole of the automatic motions cease to function. The main spindle, however, as we

The driving shaft extends the whole length of the back of the machine, and ends inside a casing in which are enclosed change gears driving the horizontal shaft immediately below the driving shaft. The change gear case is well shown in Figs. 1, 2 and 10, and the shaft seen in Fig. 12. On this change gear shaft is a small pinion clearly seen in Fig. 12. This meshes with and drives another pinion on a shorter fixed horizontal shaft below. The pinion forms part of a sleeve on which there is a bevel of which the top edge is visible behind the bottom cover in Fig. 12. This bevel (Fig. 8) engages with a bevel on a short cross shaft and the latter by means of worm and a large worm wheel, 20, drives the cam shaft, 21, in front of the machine (Figs. 1, 5 and 8). On this shaft are arranged all the cams and dogs controlling the automatic actions of the machine, and its speed can be arranged through the change gears between the driving shaft and the shaft next below

it, for turning out up to 180 pieces an hour, *i.e.*, the cycle of complete operations can be repeated up to this number of times.

The cam shaft carries three cams and three discs, the latter carrying dogs which operate various trip levers. In Fig. 5, 22 is the main or lead cam which provides every back and forward movement of the turret necessary for the completion of any specified job, for which this cam has to be specially designed. The first trip lever, 23, controls the clutch through which the chuck and bar feed cam drum is operated. The next lever, 24, is the speed clutch trip lever. This throws in or out of action the clutch working a drum cam on the driving shaft which operates one of the two hanging levers seen immediately below the speed box and already referred to. The other lever of this pair works, it will be remembered, the forward and reverse clutch in the speed box. This is thrown by another small drum cam well seen in Fig. 12, the clutch of which is controlled by the lever, 25, and its dog carrier. On the same carrier dogs are arranged to regulate an accelerated movement through lever 26, while lever 27, and its dog carrier are concerned with tripping the clutch of the turret indexing gear. The disc cams, 28 and 29, control the action of the front and back cross slides. The accelerator movement is provided to speed up the cam shaft temporarily so that a lead cam originally designed for a long piece of work may be employed for a shorter piece without too much lost time resulting. In Fig. 12 on the driving shaft there will be noticed a large gear wheel, meshing with a small pinion mounted on a sleeve on the change gear shaft below. When the accelerator is thrown in, the clutch engaging the ordinary pinion with the drive from the change gear box is thrown out, and the small pinion clutch engages so that the drive is then direct from the larger gear to the bevels through the small pinion and intermediate gears, close to and below it, instead of through the change gear box as previously described. This accelerator motion gives the front cam shaft a constant speed of 2 r.p.m. Working in conjunction with each of the trip levers is a stop lever pivotted on the same shaft (Fig. 5). Each trip lever works on a cam forming part of the moving portion of the clutch it operates, and the stop lever comes into play by engaging with a slot in the loose part of the clutch and holding it in the correct position as the clutch is disengaged.

The next motions to which we shall direct attention are the turret and turret slide movements. The lobes of the lead cam, 22, transmit an up and down movement to the double lever, 30 (Fig. 5). At the inboard end of this lever is a bevel toothed sector which meshes with the combined bevel and straight pinion, 31. The straight portion of this pinion engages with a rack (Fig. 6) on the bar, 32, and as the roller on the lever, 30, follows the cam profile, this bar is alternately drawn in by the pinion, and allowed to return under the influence of the long spring seen in Fig. 6. On the bar is mounted a drum, 33, fitted at its right-hand end as shown in Fig. 6, with a gear having 96 teeth. This gear wheel is in constant mesh with a small pinion on the driving shaft at the back of the machine, the latter pinion being long enough to allow for the maximum longitudinal travel of the drum gear, across its face. The small pinion on the driving shaft forms part of the indexing gear, and its clutch is controlled by the lever, 27, already referred to. The indexing gear which is independent of the gear moving the turret slide to and fro is best shown in Fig. 2. Part of it is visible in Fig. 12. Referring to Fig. 2 the disc, 34, is driven from the driving shaft by worm. On the disc is a crank pin which as the disc revolves engages with slots in a back plate fixed to the turret spindle, causing the back plate and turret to revolve through one position. Fixed to the same shaft as the crank disc is a cam, 35, which operates a crank lever controlling the indexing motion clutch. The combined action of turret and indexing gear is as follows. The turret and slide are drawn towards the headstock, the drum, 33, not revolving. When the cam lever passes over a lobe the turret slide recedes as far as the depression following the lobe will allow. The small pinion meshing with the drum gear wheel is then clutched in, and the drum revolved. The first effect of this, owing to the slide driving pin, and cam groove on the drum, is to force the drum forward (to the right in Fig. 6) till it is hard against the bulkhead in the bed. The stiff spring inside the drum relieves the shock of this movement. While the drum is in this extreme position its revolution is completed and the slide with the turret is carried back by the cam guide for the slide driving pin, to the extreme left, when the crank on the disc, 34, which is now being driven by the worm, engages with a slot on the back plate, and the turret is indexed one position. At the end of the main draw bar is a collar and shearing pin so that if a jam occurs and the turret slide sticks the pin will shear and no damage will be done to the machine.

The turret is locked in position by an horizontal taper pin being pushed into a socket at the back of the turret near its outer edge. This pin will be seen in Fig. 12. It is withdrawn before indexing, and reinserted in the new socket under the action of a lever operated by a scroll cam on the disc, 34, the two being brought into contact at the correct moment by the backward movement of the slide. The index locking pin can also be withdrawn by the handle seen in Figs. 2 and 12.

The turret, Fig. 7, is mounted on an horizontal spindle. It has six positions, while the face is arranged with additional Tee slots so that as many as thirteen tools can be fixed to it at once. The turret plate is 15 in. in diameter, and the tools are bolted directly to the plate. The maximum and minimum distances from chuck face to turret are respectively 8⅞ in. and 3⅞ in.

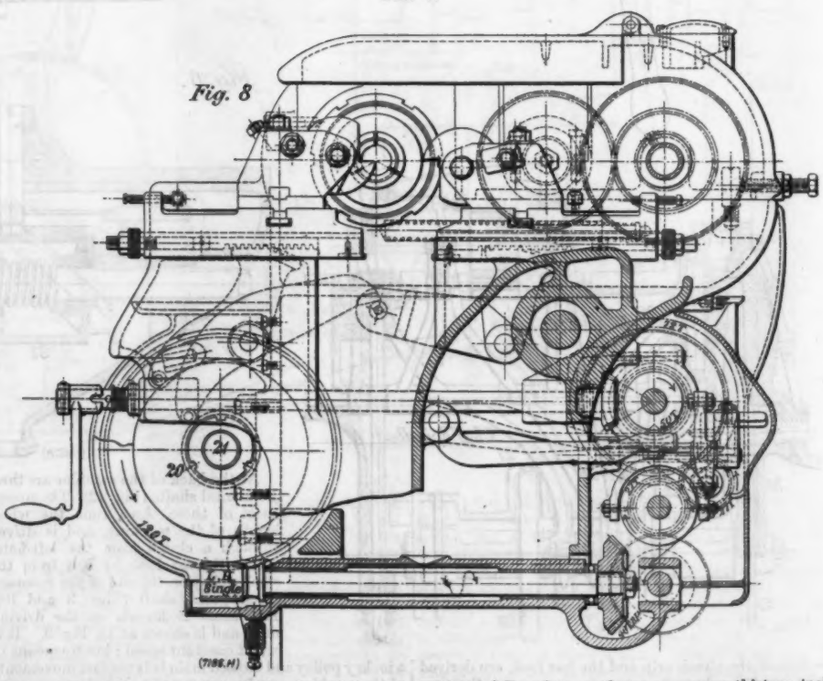
We now come to the cross slide mechanism. As already indicated the cross slides are operated by cams, 28 and 29, on the cam shaft. The cross slide gear will be easily followed from Fig. 8, which gives a section of the machine taken in line with the large worm wheel

2-IN. AUTOMATIC SCREW MACHINE.

CONSTRUCTED BY THE BROWN AND SHARPE MANUFACTURING CO., PROVIDENCE, U.S.A.

FIG. 7.

Fig. 8



2-IN. AUTOMATIC SCREW MACHINE.

CONSTRUCTED BY THE BROWN AND SHARPE MANUFACTURING COMPANY, ENGINEERS, PROVIDENCE, RHODE ISLAND, U.S.A.

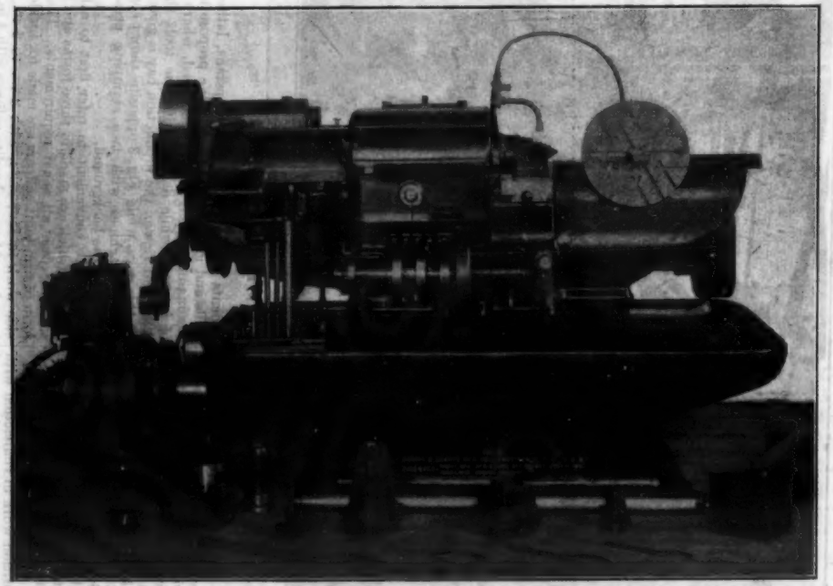


FIG. 9. FRONT VIEW OF MACHINE.

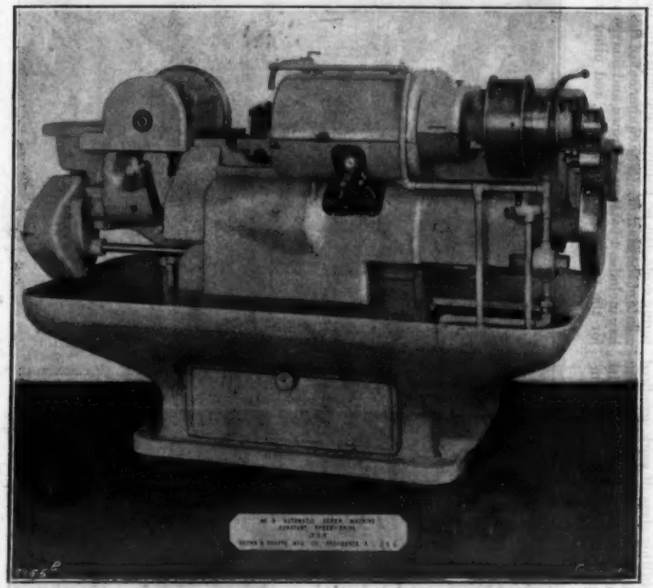


FIG. 10. BACK VIEW OF MACHINE.

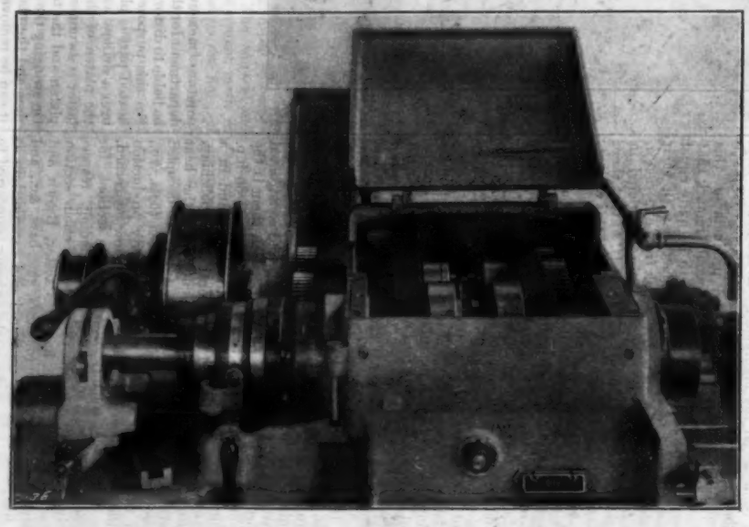


FIG. 11. VIEW OF HEADSTOCK AND BAR FEED.

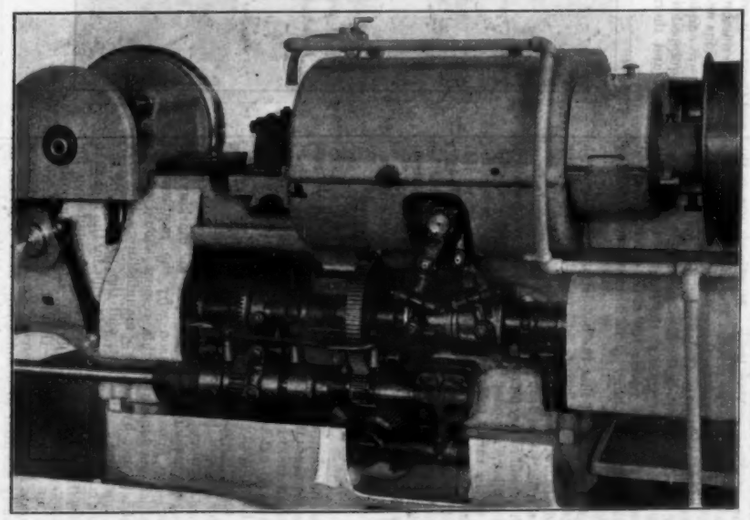


FIG. 12. VIEW OF DRIVING SHAFT AND CHANGE-SPEED SHAFT.

and cross shaft driving the camshaft. The cross slide cams operate two levers, one of which by a quadrant and rack operates the front slide, while the back slide is worked by a similar quadrant and rack but through an intermediate rocking lever. Movement across the slides of 2½ in. is allowed for. The tools used are ring tools. The slides can be operated separately or together. Fine adjustment is provided for the tool posts. Hand operation is also possible. The hand crank shown in this figure at the front of the machine drives by means of bevels the main driving shaft at the back of the machine. This is necessary for setting up, &c.

It will be noticed that the bed is cut away beneath the turret, allowing chips, &c., to fall clear into the trough below, and giving ample clearance for the turret tools. The trough forms an oil reservoir from which a small rotary pump at the back, below the driving shaft pulley, supplies lubricant through a flexible tube to the turret tools. The flexible tube carries the lubricant to the turret spindle which is hollow, and it is forced through this to the tools.

The floor space covered is about 4 ft. 10 in. by 8 ft. 2 in., and the net weight of the machine is about 5,325 lb.

MACHINISTS' TOOLS AND THEIR MANUFACTURE.

WE imagine that few of our readers will dispute the statement that the use of machinists' tools of American manufacture in British shops has developed to such an extent that it has become almost exceptional to find any of British origin in use where first-class tools are employed. We are particularly referring to the class of fine tools such as calipers, dividers, scribers, scribing blocks, vee blocks, &c., used in measuring machine work and also for marking out. There is no apparent reason why the requirements of British machinists in this respect should not be completely met by our own manufacturers, but they have not been in the past, and the recovery of the market is now rendered more difficult by the fact that American tools have acquired a good reputation for accuracy, durability and finish; another important point in their favour is that they are sold at a moderate figure. For the recovery of this trade it is obviously essential to manufacture tools of equal, or superior, quality and to supply them at the same or at a lower price.

This policy has been adopted by Messrs. C. A. Vandervell & Co., Limited, of Acton, London, W. 3, who commenced the manufacture of machinists' tools at their Hove works some few months ago. We have recently inspected the works and products of this firm, and with regard to the latter would remark that in accuracy and finish they appear to be quite equal to similar tools of American manufacture. Of their durability we cannot, of course, speak from experience, but this property has been carefully considered in the design and manufacture of the tools, so that there is no reason to anticipate any deficiency in this respect. We also understand that the important *desideratum* with regard to selling price above referred to has been completely attained. The particulars of these tools and of the manufacturing methods adopted for their production should therefore be of interest.

The works, which provide occupation for about 250 employees, are at Portland Road, Hove, about 2½ miles from the centre of Brighton and not far from Portslade Station. They were put down and equipped during the war for the manufacture of magneto parts, but this business having declined has been transferred to the firm's Acton works, where their well-known lighting sets and electrical accessories for motor cars are also made. It was therefore decided to employ the Hove works mainly for the manufacture of small tools, but jigs and fixtures and press tools are also made there for use in the Acton works as well as for outside clients. The buildings consist of two main bays both measuring 220 ft. long and 30 ft. wide and constructed of brickwork with timber roofs. Between them is the power plant consisting of two 44 h.p. and one 60 h.p. Tangye gas engines running on town gas, and in a side extension are situated the general stores, polishing, plating and enamelling departments, and the heat treatment department. One main bay is occupied entirely with the production of jigs, press tools, &c., and the other is devoted to the quantity production of the small tools with which we are now concerned. The former is roughly divided into sections for inspection, fitting, machining and grinding, respectively. The equipment of the inspection section includes a Scleroscope hardness tester, Brown and Sharpe test centres, micrometers, sine bars, &c., and all jigs and tools are measured and examined in it before passing out of the works or being transferred to the production bay. The fitting and machining sections require no particular comment, but we may mention that the latter includes Hendey-Norton, Bradford and other lathes, Brown and Sharpe, Cincinnati and Milwaukee milling machines, and a battery of Gould and Everard shapers. A view of the machining section is given in Fig. 1 on this page. The grinding section is equipped with Brown and Sharpe, Heald and Oerstedlin grinders.

For the numerous hardening, tempering and annealing operations necessary in this class of work, gas-fired muffles are employed, the heat treatment department being equipped with a number of these as well as with optical and thermo-couple type pyrometers for temperature measurement. The method used in this department for the hardening of flat parts which would be liable to distortion during the operation is interesting. For this purpose a fly press has been adapted and the heated part is placed on a small spring-mounted table over a shallow water tank. The table is situated under the platen of the press so that when the arm of the latter is swung round, the part is gripped between the platen and the table and pressed down into the water. On swinging the arm in the opposite direction the table rises and the platen releases the quenched part so that it can be removed.

The whole of the repetition work in connection with the production of small tools is carried out in the second main bay, and boys ranging from 14 years of age upwards are employed exclusively for this work except, of course, that skilled tool setters are required for setting up the machines. This has been rendered possible by the extensive employment of jigs and fixtures, and automatic machines, and attachments which relieve the operative of all responsibility for the accuracy of the work, and it is only by this means that manufacturing costs can be reduced sufficiently for the requirements of the market. The equipment of the production bay includes a battery of Brown and Sharpe automatics for the manufacture of screws and other small components and a full range of capstans, lathes, millers, drills and grinding machines. We propose to indicate the manufacturing methods adopted, where these are of interest, while dealing with the tools themselves. A general view of the production bay is given in Fig. 2 on this page, while Fig. 3 opposite shows some of the milling machines with two stamping presses partly visible in the background.

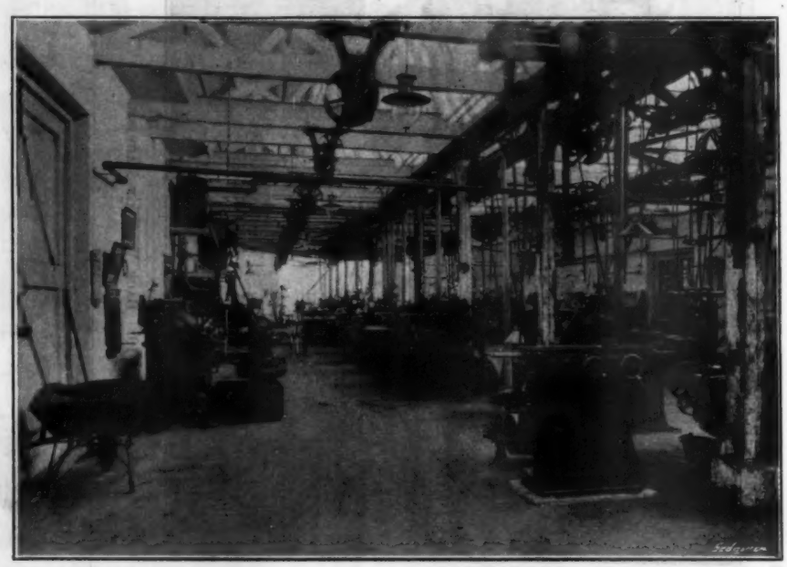


FIG. 1. MACHINING SECTION OF THE JIG AND TOOL BAY.

FIG. 2. GENERAL VIEW OF THE PRODUCTION BAY.

It will be convenient to refer first to calipers and dividers, which are made in three forms and in various sizes to cover all usual requirements. The common form of firm-joint calipers are made for inside and outside work in four sizes, with 3 in. to 6 in. legs, and two sizes of hermaphrodite calipers with 4 in. and 6 in. legs are also made with firm joints. In these calipers the main stud is threaded and screws into the washer,

which is fixed by means of flats engaging with the sides of the holes in the legs. A fibre washer is fitted between the legs to give an easy movement. Spring calipers and dividers with screw adjustment are made both with flat legs and with legs of circular section, the latter form possessing considerably greater lateral stiffness, and thus being particularly suitable for toolmakers' use and other accurate work. Another advantage of this type is that the adjusting screw

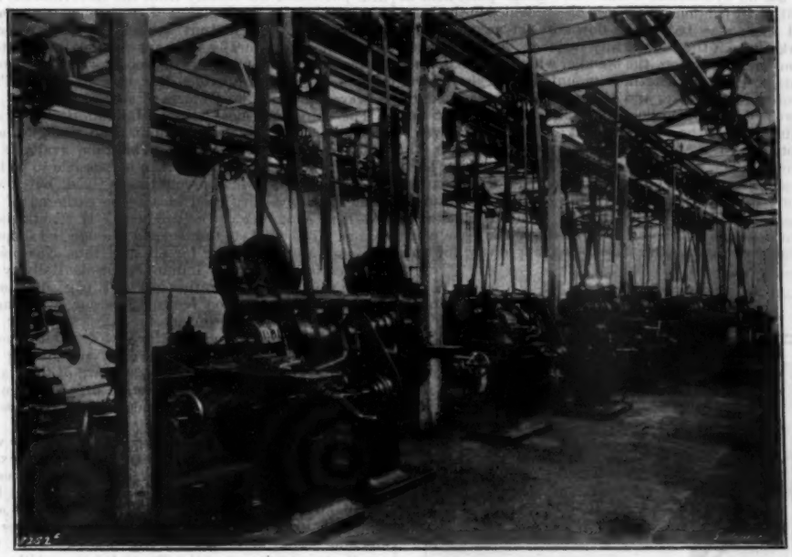


FIG. 3. MILLING MACHINES IN THE PRODUCTION BAY.

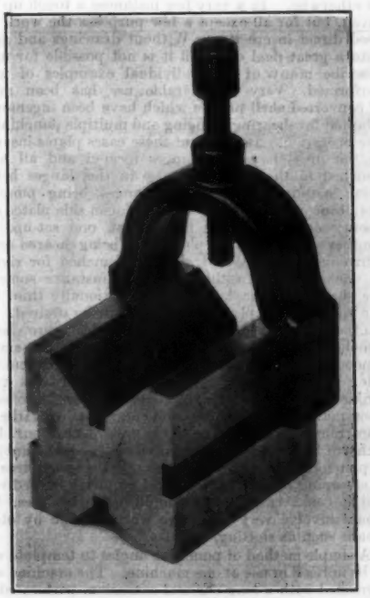


FIG. 4. VEE BLOCK.

works in the plane of the legs. Calipers of both forms are made for inside and outside work, the flat-legged type in four sizes, ranging from 3 in. to 6 in., and the toolmakers' type in five sizes from 2 in. to 6 in. The dividers are made in a similar range of sizes.

The legs for firm-joint calipers are stamped out of sheet steel, hardened and tempered throughout, while those for spring calipers and dividers of the flat-leg type are similarly heat-treated, but are formed from straight bar stock. The curved legs for outside calipers are bent to form in dies, and the tapers for the legs of inside calipers and dividers are formed by milling. In this type of tool the adjusting screw, which is of oil-toughened steel, works in short pillars, both of which can swivel on the legs, and a loose conical washer is fitted between the knurled adjusting nut and the pillar on which it bears. All parts of these tools are made at the Hove Works excepting the springs, which, being a highly specialised product, are purchased from a spring manufacturer. The flat faces of the legs are finished on "Linishing" machines, of which a battery of 12 are employed. For this operation the

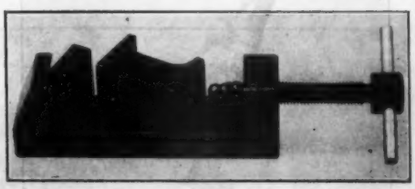


FIG. 5. VICE CLAMP.

legs are placed on the face of a holder, in which they are held by a permanent magnet, the drag of the emery cloth band being taken by short pegs fitting into the hole in each leg. The straight edges of caliper legs are finished on an emery cloth band running over a fixed bar, in which a number of grooves are formed parallel with the direction in which the band travels. The grooves are only slightly wider than the thickness of the legs, so that when the edges of the latter are pressed down into one of the grooves the form of the band is such that the sharp corners of the legs are nicely rounded off. The method of finishing the concave inner edges of outside calipers is similar, except that polishing bobs, consisting of cast iron expanding cylindrical shells covered with emery cloth, are employed. Grooves are formed in the shell to round off the corners, as above described, and the diameter of the shell is chosen according to the size of the calipers being made, so as to give the necessary radius in the plane of the legs. The screws and washers for firm-joint calipers are, of course, made in automatic machines. The bevelled edges are finished by holding the shank in a spring collet in a high-speed lathe head and subjecting them to the polishing action of fine emery cloth carried on the edge of a small steel disc. The latter is driven by a long round leather belt, and is mounted at the correct angle in a slide carried by a bracket on the lathe bed. A hand lever is provided, so that the operator can bring the edge of the disc up to and away from the work.

The toolmakers' calipers and dividers as previously mentioned, have legs of circular section, and the stock for these is purchased in the form of round bars. The tapered ends are formed by cold swaging in a rotary swaging machine, this process effecting a considerable economy in material in comparison with turning and also producing stiffer legs with better finish. The steel has, of course, to be selected so as to be amenable to the severe treatment of swaging, but note is kept of each batch supplied to the machine so that if any defects develop during the process the origin can be traced. The process is carried out in five stages and the material is annealed between each. In tools of this class the adjusting screw passes through one leg and is connected to the other leg by a pin joint. The latter is formed in a blind hole, and a moment's consideration will show that one side of this hole, and also of the through hole in the other leg, must be chamfered off to clear the screw as the legs of the tool are opened out. Both holes are formed in a similar manner by means of a small vertical end mill, the leg being held horizontally in a jig on the table of the drilling machine. A cylindrical hole is first milled out at right angles to the axis, either right through the leg or to the required depth, and, after withdrawing the mill, the leg is tilted in the jig in such a manner that the leg turns about the lower end of the hole. The mill is then brought down again so that it mills out the side of the original hole and the operations are repeated five or six times until one side of the hole is cut away to the required extent. The seatings for the roller forming the main joint for the legs are milled out with a small form mill, and the legs are bent to the correct shape for calipers or pointed for dividers, but these operations call for no special comment. It should be mentioned that in spring dividers of both the toolmakers' and flat-legged patterns a knurled finger grip is screwed into the top of the spring for convenience in handling.

Vee blocks and clamps form another important item of the firm's productions, and these are made in three qualities, viz., of tool steel, of case-hardened mild steel, and of cast iron. The tool steel blocks, one of which is illustrated in Fig. 4, are intended for precision work, and are sold only in pairs, which are marked with the same number to ensure their being used together. The dimensions of the blocks are 1¼ in. by 1¼ in. by 1⅛ in., and in any pair of blocks these are in agreement to within ·00025 in. The larger vee groove is suitable for rods up to 1 in. in diameter, and the grooves on the sides for the clamps are of rectangular section, as shown in our illustration. The clamp itself is of malleable iron.

For the manufacture of these blocks carbon steel in the form of bars 1⅛ in. square in section is used, and one bar of each batch purchased is broken to observe the fracture. The bars are first cut off into 7¾ in. lengths, and the vees and the grooves for the clamps are rough milled. The piece is then cut into four, after which the separate parts are treated in a gas muffle and tempered in oil. They are then inspected and tested for hardness by the Scleroscope, and afterwards returned to the hardening shop for the seasoning process. In this they are heated to 150 deg. Cent. in an oil bath and plunged into ice-cold water ten times in succession, the whole process occupying about a day. The next operation is rough grinding, in which the parts are finished to within ·004 in. of their final dimensions, and after this they are put into store for a period of three months. During this period one block from each batch is checked for size at weekly intervals to ascertain if any distortion has taken place, this precaution serving to check the previous operations and the quality of the steel. After final grinding they are kept in the inspection room for a further period of a week and tested every day for distortion, any changes that may occur being carefully recorded for future guidance as to the steel and its treatment.

The case-hardened vee blocks are shorter than those above described, being only 1¼ in. long, although the other dimensions are similar. They are intended for work of a less exacting character and are machined only. They are sold in pairs, and, to ensure correct alignment, each pair is mounted on a rod 6 in. long, which passes through longitudinal holes in the blocks. The holes are fitted with spring collets to give a friction grip. Two grooves are provided in the sides of these blocks, so that the clamp can be raised or lowered to take work of different diameters. Rods up to 1¼ in. diameter can be held in this way. In making these blocks the square bars are first cut to a length suitable for making four blocks and normalised. The vees and grooves are then milled, the parts are sawn to final lengths, and the holes for the longitudinal rods are then drilled. The final operation is case-hardening, these blocks not being ground.

The cast-iron blocks, above referred to, measure 1¼ in. by 1¼ in. by 2 in., and are of cheap construction for comparatively rough work. Each block has four "vees," and they are made from bars cast in a cruciform section about 1 ft. in length. The bars are first rough milled and sawn to length, and the blocks are then subjected to a seasoning process, in which they are heated in oil to 350 deg. C. and plunged into cold water five times in succession. After this treatment they are completed by fine milling. The blocks are

supplied in pairs and are capable of taking work up to 1½ in. in diameter.

Fig. 5, on page 291, shows a toolmaker's vice clamp made by the firm in one size only to take work up to 2 in. wide. The main part is a case-hardened drop forging, and the flat jaw and distance-piece are of mild steel rolled to section and also case-hardened. Both loose parts are provided with a hole in which a spring wire ring is fitted, and this ring snaps on to the ball end of the screw, as will be clear from our illustration. As now made, the packing piece has a vertical vee groove formed on its front face to enable a rod to be held approximately vertical, and a horizontal groove is made in the main jaw to hold a rod in the horizontal position. The usual spring friction device is fitted in the head of the screw for holding the tommy bar, and a countersunk hole is drilled in the base to enable the clamp to be screwed down to a bench. Toolmakers' clamps of the double-screw type are made in five sizes, with capacities ranging from ½ in. to 2½ in. The jaws are made of case-hardened steel milled all over, and afterwards case-hardened. In this operation the tapped holes for the screws are filled with fireclay to protect the threads and also to prevent undue weakening of the section at the hole by the hardening. The screws are of a special quality of mild steel

Fig. 6.

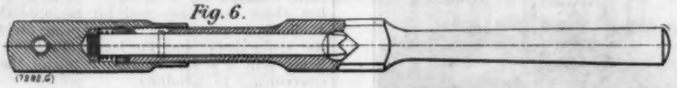


FIG. 6. TAP WRENCH.

toughened by heat treatment, and they are made a slack fit in the holes to ensure easy working.

Machinists' squares are made in seven sizes, with blades ranging from 1 in. to 7 in. in length, and the method of manufacturing them is of interest. The stock or base is built up of three parts of carbon steel—two thick outer parts with a shorter central distance-piece being employed; the thickness of the latter is slightly greater than that of the blade, and the widths of all the parts are equal. After hardening and tempering, and grinding all over, the three parts of the stock are riveted together so as to leave a central slot at one end, and the outer surfaces are again ground to remove any slight irregularity due to the riveting and to give a good finish. The finished blade, which is of special steel, is then placed loosely in the slot with a piece of tinfoil on each side of it between the blade and the stock, and while the square is held in a fixture which ensures the blade and stock being kept accurately at right angles, a heavy electric current is passed laterally through the end of the stock and blade to melt the tinfoil and thus form a soldered joint. It should be mentioned that before riveting together the ends of the inner faces of the thicker parts of the stock are carefully tinned, as also is the part of the blade which fits in the slot. After making the joint in this way no further treatment is necessary, as the temperature is only raised just sufficiently to melt the tin without affecting the temper or causing any discolouration. The advantage claimed for this joint is that the blade is held over the whole surface enclosed in the stock instead of at two or three points, as in a riveted joint. It is also pointed out that if a joint should fail, the failure would be general and would be detected immediately, whereas the slight looseness of a riveted joint might lead to the production of much inaccurate work before being noticed. At our suggestion a number of squares were tested to destruction to determine the strength of the joints. In the case of four 4½-in. squares tested, the pull required to remove the blade amounted to 15 cwt, and in the case of two other squares of the same size the pull required was 1 ton. In all cases the load was applied to the blade at a distance of 1 in. from the base of the square, of which the stock had a width of ½ in., while the width of the blade enclosed in the stock was ¾ in.

Of the remaining products of the firm, we may mention a universal bevel, pocket scribers and screwdrivers and tap wrenches, all of which are of good design and finish, but the processes of manufacture involved in their production call for no detailed comments. The tap wrenches are made in three sizes, designated as 3 in., 6 in. and 9 in. from their overall dimensions. The smallest is of cheap and simple form, the tap being held by the rotating end of the tightening screw. The design of the two larger sizes, both of which are similar, is illustrated in Fig. 6 on this page. From this it will be seen that the tap is gripped between two vees, one formed in the central hole of the holder, and the other on the end of a rod which slides in a hole drilled longitudinally through one end of the holder. This rod is adjusted by means of a screwed thimble provided with a hole for a tommy bar, and is prevented from rotating by means of a pin working in a slot in the screwed part of the holder. A short helical spring is arranged as shown in the illustration to open the jaws when the thimble is screwed back. The two larger sizes are made of carbon steel hardened and oil tempered, while the smallest size is case-hardened.

Finally, we may refer to the scribing block illustrated in Fig. 7, which is the only other product at present on the market, although other lines are being developed. The scribing blocks are made in two sizes, one with a base 3 in. square and the other with a 3½ in. square base. In both cases the base blocks are of cast iron, and have a vee groove milled in the bottom surface for use on cylindrical work. Two gauge pins, held in position by friction springs, are also provided in the base, and these may be pushed down to act as guides for working from the edge of any surface. As will be seen from our illustration, the spindle, which may be either 9 in. or 12 in. in length, is mounted on a short lever pivoted to the base, and this lever can be rocked by means of the milled-headed screw shown for the fine adjustment of the scribing point; the rocking lever is kept up to the adjusting screw by means of two stiff springs. The spindle is attached to the rocking lever by a spring clamp, so that it will not slip, but it can be firmly locked in any position by means of a knurled finger nut. The spindle, it will be noticed, can be turned downwards so as to work below the base when necessary, part of the base being cut away for this

FIG. 7. SCRIBING BLOCK.

purpose. It is also possible to remove the spindle and clamp the scriber directly on to the rocking lever for low or small work. We may also mention that the lower end of the spindle in our illustration is fitted with a small square hardened steel cutter which may be used as a scratch gauge in woodworking, &c.

In conclusion, we would add that all tools made at the Hove works are first inspected there, and afterwards undergo a further inspection at the firm's Acton works, where the sales organisation is centred. Generally we think it will be admitted from what we have said above that every care is taken both in the design and manufacture of the tools to produce reliable articles, and this being the case it is to be hoped that Messrs. Vandervell's new venture will achieve the success it appears to us to deserve.

THE NOTTINGHAM CARRIAGE AND WAGON WORKS OF MESSRS. CAMMELL LAIRD AND CO., LIMITED.

THE party of engineers who visited, on Friday last, at the kind invitation of Messrs. Cammell Laird and Co., Limited, that firm's railway carriage and wagon works at Nottingham, certainly found much to interest them during their tour of the shops. There is no doubt that many of them left subsequently greatly impressed by the possibilities of some of the processes of manufacture and with the original and ingenious manner in which the problems of steel construction had been tackled.

The works in question were originally established for shell making. They were erected in 1915 by Messrs. Cammell Laird and Co., who subsequently ran them, their lay-out and equipment being specially designed for the production of 9·2-in. and 6-in. shells. Subsequently, when the supply of shells was assured, and the supply of ordnance was below requirements, the factory was turned over to the production of 18-pounders and 6-in. Mark XIX guns, and the repair of 9·2-in. howitzers. On the cessation of hostilities the firm purchased the factory from the Government, and converted it for the building of steel railway carriages and wagons. The output is now confined to steel work, though naturally it is not possible in all stock to dispense with every bit of woodwork, and a small shop is therefore provided for this purpose. This, however, presents no features of special interest.

The works are close to the Midland Railway, and the site covers 43 acres, the main shop giving an area of 10 acres under one roof. The time available on Friday was far too short for it to be possible to go into as much detail as many would have liked, but it was sufficient for a very good idea to be gathered of the excellent character of the product of the methods in vogue. The chief contracts going through the shops at the time were an order for all steel third-class bogie coaches for the Great Indian Peninsula Railway, of which we give an illustration in Fig. 1, page 293, and a repeat order for 40-ton hopper cars for the Bengal-Nagpur Railway, shown in Fig. 2. An order for 2,500 steel 12-ton wagons for the New Zealand Government was completed some time ago, and during the visit on Friday last examples were shown of the manufacture of various parts for these, in order to demonstrate what can be done to reduce costs in the case of orders of reasonable size.

The main point which impressed itself upon one was the care and trouble which was taken to secure exact repetition of the work. There were many instances of ingenious solutions of lathe and other problems, but the greater interest attached in this case to press and punching work, and to the use made of fixtures in erection. We were particularly struck with the excellent maintenance of the dies and shears. Although in many cases the parts produced were near the end of the contracts the work was so excellent as to leave no burr or fin, and to require no finishing at all by hand or otherwise. In a very few instances a touch up was given, but for all except a few purposes the work was used direct in erection. Without drawings and going into a great deal of detail it is not possible for us to describe many of the individual examples of work performed. Very considerable use has been made of converted shell presses which have been ingeniously adapted for shearing, flanging and multiple punching at one operation. In many of these cases plates inserted in the press have the flanges formed and all holes punched in the panel and also in the flanges before being withdrawn, the three flanges being punched simultaneously with the body. Wagon side plates and doors were thus being finished at one set-up. In another case wagon floor plates were being sheared on all four edges at once, and all holes punched for rivets, in one setting. In this particular instance some of the shavings sheared off were exceptionally thin, but the edges of the plate left nothing to be desired. In another press headstock gusset plates were being punched, all holes, large and small being cut simultaneously without the least burr or rag on the underside. The clean finish of all this work was very striking indeed and made a considerable impression upon many of the visitors, some of whom we gathered from remarks dropped in the course of the tour, had hitherto held rather conservative views on the subject of punching and shearing. Among other parts treated in stamping presses were several requiring curved cuts which could easily be accomplished with dies, but would involve very expensive work if done by other means such as slotting, &c.

A simple method of punching angles to template was to be noticed in use at one machine. The machine was furnished with a long channel extension, perforated at intervals by cross slots. The slots were cut at distances apart corresponding with the pitch of the rivets, the first one being the correct distance from one end of the angle. The lug of a stop fitted with a handle was inserted in each slot in turn, and the angle fed hard up against the stop and the punch operated. Two men fed this machine, and the holes were punched practically as fast as the treadle could be worked, the correct pitch being secured without any marking off or careful setting. A number of other interesting examples of this class of work might be cited, but we can only refer to one or two. One was the shearing of the bellied solebar plates of the Bengal-Nagpur hopper wagons shown in Fig. 2. These were cut under large guillotine shears, the setting being by dowels, without marking off; the finished edge for a thick plate was in this instance particularly good. In another case an horizontal hydraulic press was being used for punching all holes in tapered channel end

stanchions, and for cutting the flanges on a very long taper. Such work done on a planing machine, or by other means would involve great expense, whereas once the set-up has been designed and made, the work could be put through this press as fast as men could handle it.

Messrs. Cammell Laird have now in course of erection at the works a new press for pressing cold any length up to 40 ft. The press is formed of two units, and one is so far advanced that work was being done on it at the time of the visit. Cold pressing is a feature of the firm's work generally, and providing the job is suitable it is always preferred to hot work. The examples shown were undoubtedly very good indeed. A useful application of electric welding was to be seen in the welding of corners in trough-shaped pieces pressed out of cut plate. The corners were much sharper and cleaner than would be possible with a pressed sheet job, and the metal at the actual corner was of course built up and thickened in section by the weld metal. It would take more space than we can now devote to the subject to detail all the interesting methods in use, and we can only give a few and rather disconnected examples of what was to be seen in other parts of the works. In drilling long solebar channels, we noticed that the piece was fixed in one template which covered all three operations of drilling the two flanges and web. The fixture was carried on trunnions, fitted with a checkplate with a locking bolt for 90 deg. positions, so that on one flange being completed the piece could be revolved 90 deg., and the web drilled, and so on. This was in use on a multiple head drilling machine.

One of the prettiest pieces of high speed work was the use made of a vertical mill for trimming the flanges of plates. The job was actually the trimming of the outer and inner flanges of the large bracket plates under the hoppers of the Bengal-Nagpur wagons illustrated. These plates were mounted on the table of a boring mill, of which the two heads were fitted with tools having cutting faces about 6 in. and 4 in. wide for the inner and outer flange respectively. On the table being revolved the flange edge in each case traversed to and fro beneath the wide tool, with the result that a continuous and rapid cut was taken in spite of the irregular shape of the piece of work. Frequent use is made of wide form tools, as for instance in the case of bogie pivot castings, the cup of which is turned with tools formed to the radius of the cup. Continuous milling was also to be seen in operation, one instance being the facing of bogie side-bearing blocks. A number of these were mounted on a revolving table, while the cut was taken by two multiple tool milling cutters running on vertical spindles. Several adaptations of hollow milling were in evidence, for work too large to be swung in a lathe. In these cases the work was mounted on a fixture on the lathe bed and the hollow mill on the nose of the lathe spindle. The work thus dealt with included brake beams, brake shafts and other awkward pieces.

An ingenious forming device was in use for turning buffer heads. The cutting tools for the front and back faces were mounted on levers on vertical pivots. The back extensions of these levers were arranged with curved faces, and between them was placed a wedge block. As the cross slide traversed in and out across the buffer head the block forced the levers apart,

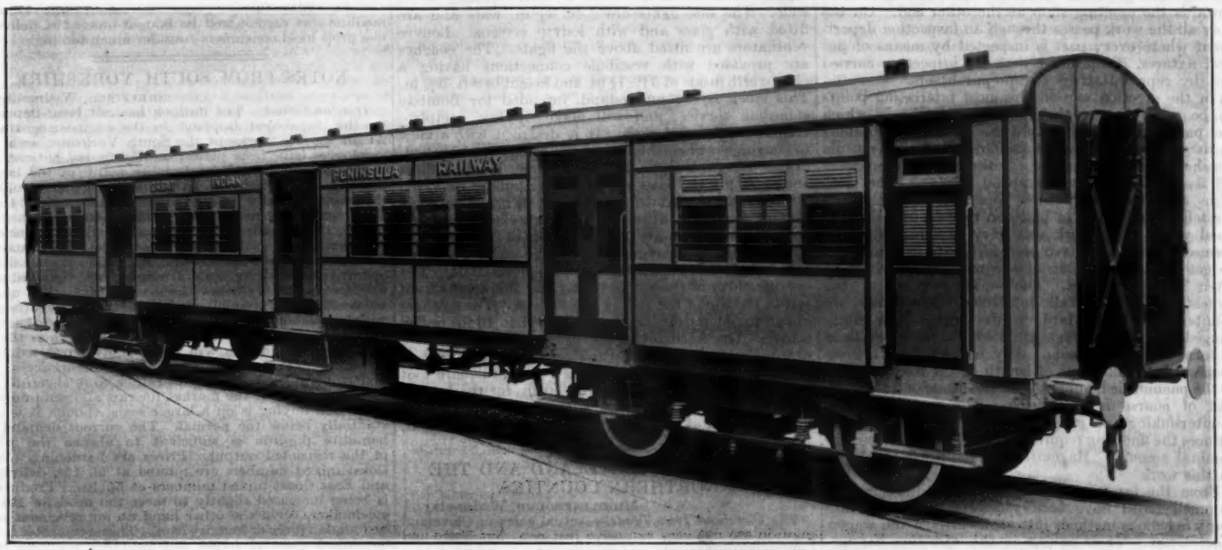


FIG. 1. THIRD-CLASS STEEL BOGIE COACH FOR THE GREAT INDIAN PENINSULA RAILWAY.

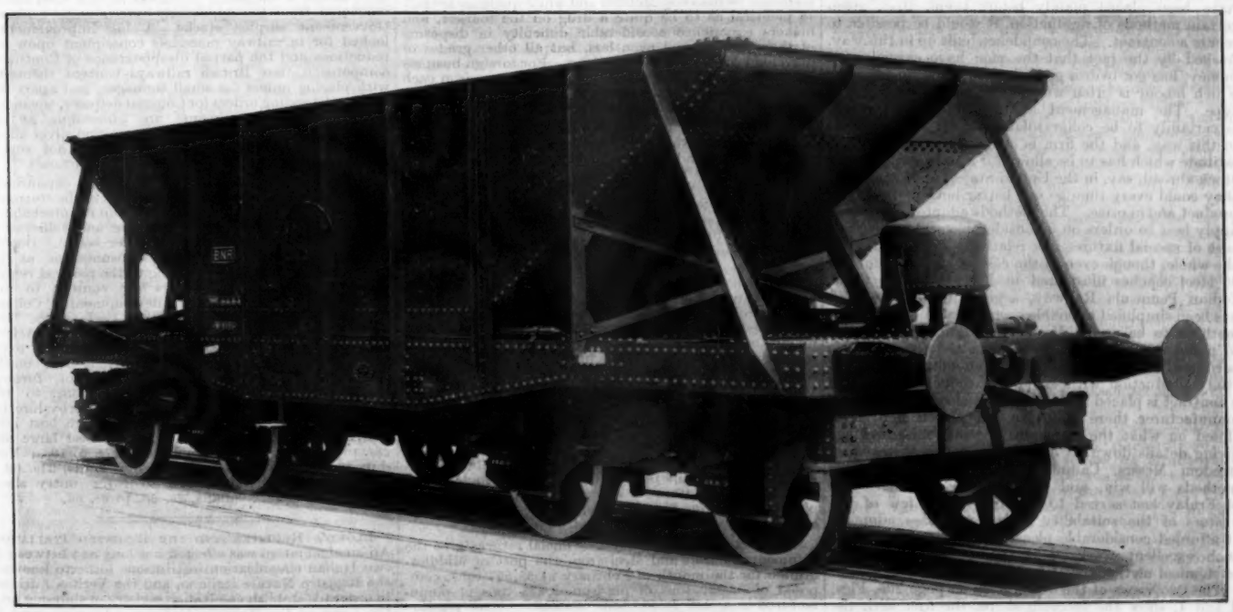


FIG. 2. 40-TON HOPPER WAGON FOR THE BENGAL-NAGPUR RAILWAY.

or *vice versa*, and controlled the tools to give the profile required for the head. It may be remarked that central buffers are forged by Messrs. Cammell Laird in six operations, from the billet. No machining is used for finishing, with the exception of drilling the shackle pin holes, &c., and screwing the end of the shank to take the large nut. The whole of the square and round portions of the shank are finished to size by forging.

The shops generally are laid out so that raw material comes in on one side and the work gradually passes through the processes of manufacture and gravitates towards the erecting shop at the other end. On the way all the work passes through an inspection department where every part is inspected by means of jigs and fixtures, independently of the inspection carried out by representatives of the purchasers.

In the erection section the most interesting points to be noticed were the excellent manner in which the parts came together, and the good finish obtained in riveting. In the case of the Great Indian Peninsula coaches illustrated in Fig. 1, the side sections were all assembled and riveted up on fixtures. The roofs were assembled on fixtures and the roofing sheets stretched and drilled in place on this set-up to ensure good work. The work was very expeditiously performed, as the firm have been fortunate in being able to get away from some of the restrictions which so often hamper output. The small riveting of the panels and sides is all done cold. The holes are countersunk to standard on the outside; carefully gauged countersunk rivets are used and the round head is formed on the inside. Any irregularity of these heads due to difference of length or the manipulation of the pneumatic hammer, is on the inside of the coach, and of course is not visible. The use of outside countersinking and gauged rivets closed on the inside reduces the finishing required on the outside to a merely nominal amount. Magnetic holders-up are employed on this work.

From the foregoing it will be evident that Messrs. Cammell Laird have been successful in introducing many ingenious methods into steel carriage and wagon construction. Their success in this direction has undoubtedly been due to a large extent to the tactful way in which the problems have been tackled. We understand it to be the practice at the Nottingham works always to keep the men informed of the reasons for adopting new schemes. In many cases the facts have been placed plainly before them, that, given certain methods of production, it would be possible to secure a contract. The confidence built up in this way, backed by the fact that the men have earned good money, has got over a good deal of the suspicion with which labour is often wont to view novelties of this type. The management at the Nottingham works is certainly to be congratulated on its achievements in this way, and the firm is confident that, given the latitude which has to be allowed if a railway purchases stock abroad, say, in the United States, at Nottingham they could every time go one better both in quality of product and in price. The methods adopted, of course, apply best to orders on a considerable scale, when the cost of special fixtures is a relatively small portion of the whole, though even in the case of the order for the 40 steel coaches illustrated in Fig. 1, for the Great Indian Peninsula Railway, a great deal of the work has been simplified to enable economical manufacturing methods to be used. If sufficient latitude is allowed in non-essential features of design, the freedom thus permitted will naturally allow the manufacturer to study production with a view to reducing price. If a contract is placed in America it is closed on what the manufacturer there will give. If placed here it is closed on what the purchaser specifies, his drawings giving details down to bolts and rivets. With equal freedom Messrs. Cammell Laird claim that their methods will win, and we hope the demonstration of Friday last served to convince not a few of the visitors of the suitability of the processes adopted. It afforded considerable pleasure to visit shops where such excellent work of its type, produced under economical methods, was to be seen.

The two views of the works given on page 296, Figs. 3 and 4, show the erecting shops, the first with the Bengal-Nagpur 40-ton hopper wagons, and the second with the 12-ton New Zealand Government wagons under erection. The original order for the first was for 115. The present order going through the shops is for an additional 100. The New Zealand order as previously stated was one for 2,500. A number of other important contracts have passed through the shops since they were converted from ordnance work, including cars for the London Electric Railways, Calcutta Port, the Egyptian State and other railways.

The steel bogie coaches now building for the Great Indian Peninsula Railway, illustrated in Fig. 1, are 67 ft. 10¼ in. over headstocks, and 71 ft. 7 in. over buffers. They accommodate 100 passengers, and the tare weight is about 35 tons. The distance between bogie centres is 48 ft., each bogie having a wheel base of 10 ft., the wheels being 3 ft. 7 in. in diameter on the tread. The height from rail level to the top of the roof arch is 12 ft. 9½ in. and the overall width 10 ft. The third-class coach is provided with three double sliding doors on each side, and two single hinged doors at the ends. In the case of coaches with a luggage compartment the latter has double sliding doors in addition. The double doors for the passenger compartments give a clear opening 3 ft. 6 in. wide, the doorways measuring 4 ft. 4 in. between posts. The hinged doors are 2 ft. 4 in. wide, while the double doors for the luggage compartments have a clear opening 4 ft. wide. The side lights are 2 ft. 4¼ in. wide and are fitted with glass and with louvre screens. Louvre ventilators are fitted above the lights. The coaches are provided with vestibule connections having a clear width inside of 3 ft. 1¾ in. and height of 6 ft. 5⅞ in. This stock is, we understand, intended for Bombay suburban service, and will make up five complete trains of eight cars each. It is designed with a view to conversion when this service is ultimately electrified.

The Bengal-Nagpur Railway hopper wagons illustrated in Fig. 2, have a length over buffers of 32 ft. 10 in., and over headstocks of 28 ft. 8 in. The bogie centres are 18 ft. apart, and the wheel centres 6 ft. apart; the wheels are 3 ft. 1 in. on the tread. The length of the hoppers at the top edge, inside, is 25 ft. 2 in., and the width outside side plates 9 ft. The overall width of the car is 10 ft., and the height from rail to the top of the coping is 9 ft. 3 in. The solebars are 10 in. deep over the bogies, bellied to 16 in. in the centre. The headstocks are of 10 in. by 23·55 lb. channel section. The side posts are of light channels and bulb angles. The plating is 7 lb. per square foot for the sides of the hopper, and 10 lb. for the hopper bottom. The car is braked with two 18-in. vacuum cylinders, one at each end, and with hand-lever gear.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Actual sales of Cleveland pig-iron are not very extensive just now, but home and foreign inquiries continue fairly numerous, and producers look for growth of Continental trade. While there is still a little successful foreign competition in home markets, quantities of pig-iron purchased from abroad have shrunk to small proportions, and there is a pronounced feeling that sales of imported iron, to any extent, need no longer be feared. Mottled and white qualities are still so plentiful as to be quite a drug on the market, and makers experience considerable difficulty in disposing of them at 75*s.* and even less, but all other grades of Cleveland pig-iron are very strong. For foreign business as well as for home trade, No. 1 and siliceous iron each stand at 95*s.*; No. 3 G.M.B. is 90*s.*; No. 4 foundry, 87*s.* 6*d.*; and No. 4 forge, 82*s.* 6*d.*

Hematite.—East Coast hematite is characterised by much firmness. Supply is barely equal to current needs, and this week's addition to output by the relighting of a furnace at the Seaton Carew Works is very welcome. Some firms are so well sold that they cannot entertain new business for delivery before the middle of April. Home and export prices stand at 100*s.* for Nos. 1, 2 and 3, and at 101*s.* for No. 1.

Manufactured Iron and Steel.—Little new can be reported of the various branches of finished iron and steel, but it is some gratification to find that what slight changes are noticeable, are for the better. There is a little more demand for structural steel, and inquiries for galvanised sheets show improvement. In many departments, however, difficulty continues to be experienced in keeping works partially running. For export trade manufacturers continue to quote well below the rates they name for home business, and are stated to be securing a fair share of the limited foreign orders for which inquiries are circulating. To home customers, common iron bars are 12*l.*; iron rivets, 14*l.*; steel billets (soft), 7*l.* 10*s.*; steel billets (medium), 8*l.* 15*s.*; steel billets (hard), 9*l.* 5*s.*; steel boiler plates, 14*l.* 10*s.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; steel joists, 10*l.* 10*s.*; heavy steel rails, 9*l.* 10*s.*; fish plates, 14*l.* 10*s.*; black sheets, 12*l.* 10*s.* to 13*l.*; and corrugated galvanised sheets, 16*l.*

Shipments of Iron and Steel.—Official returns give the shipments of iron and steel from the port of Middlesbrough for the month of February at 58,597 tons, composed of 32,329 tons of pig-iron, 2,833 tons of manufactured iron, and 23,435 tons of steel. Of the pig-iron cleared 6,895 tons went coastwise, and 25,434 tons went to foreign ports; of the manufactured iron despatched 624 tons went coastwise and 2,209 tons went to foreign ports; and of the steel shipped 3,081 tons went coastwise and 20,354 tons went to foreign ports. The largest customers for pig-iron were: Italy, 6,700 tons; Belgium, 6,336 tons; France, 4,160 tons; Germany, 3,136 tons; Scotland, 3,070 tons; Wales, 3,030 tons; Switzerland, 2,000 tons; and Holland, 1,490 tons. Once more India was the heaviest importer of both manufactured iron and steel, receiving 1,316 tons of the former, and 8,149 tons of the latter. Other principal customers for steel were, the Argentine 4,154 tons; Natal, 2,137 tons; Japan, 1,060 tons; and the Strait Settlements, 1,018 tons.

Imports of Iron and Steel.—Interesting statistics compiled by the Tees Conservancy Commission show imports of iron and steel to the Tees ports from Holland, Belgium, France, Norway, Sweden, Germany and coastwise (Wales) for the four months ending February 28 last, as compared with the same time a year ago, and with the corresponding pre-war period in 1913–14. The returns reveal that in the past four months 28,045 tons of pig-iron were imported as compared with 7,375 tons in 1920–21, and only 54 in 1913–14; whilst the quantities of billets, blooms and slabs unloaded for the period ending February 28 last totalled 17,948 tons, as compared with 12,571 tons in 1920–21, and 14,309 tons in 1913–14. Plates, bars, angles, rails, sheets and joists received from the countries named amounted to 2,340 tons, as compared with 9,482 tons in 1920–21, and 7,906 tons in 1913–14.

Coke.—Blast-furnace coke is easier, but Durham medium sort cannot well be bought under 29*s.* delivered—a price local consumers consider much too high.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The outlook has not been improved by the threatened stoppage in the engineering trades. At all the big works in the South Yorkshire area, the employees have been placed on day-to-day notices, and if the lock-out should materialise many of the largest departments will close. In addition, further trouble is threatened locally in the steel ingot-making trade. The local branches of the Amalgamated Engineering Union, the Electrical Trades Union, and the Associated Blacksmiths' Society allege that steel ingot makers, without the unions' permission, have placed semi-skilled operatives on sliding scale arrangements, thus reducing wages considerably below the district rate. The unions are seeking the sanction of their national executives to withdraw labour as a protest against the masters' action, and unless a late development occurs it looks as though steel ingot production will be partially paralysed from Saturday next. Apart from labour disturbances, the undertone in the steel trade is rather more cheerful. In certain sections of the market for raw and semi-finished materials, buying is on a larger scale, though it is substantially below the normal. The current demand for hematite pig-iron is sufficient to absorb the whole of the restricted output. Prices are hardening. West Coast mixed numbers are quoted at 5*l.* 15*s.* delivered, and East Coast mixed numbers at 5*l.* 10*s.* Production is being increased slightly to meet the needs of British steelmakers. On the other hand no improvement is to be found in forge or foundry iron. This is traceable to the continued quiet at forges and foundries resulting from the dearth of orders in shipbuilding and in agricultural and automobile engineering. Increased inquiries continue to be received from open-hearth steel makers for scrap, but merchants still decline to contract forward except at substantial premiums on current rates. Trade in ferro alloys is stagnant. Business in tool steel has not recovered from the apparently interminable release of Government surplus stocks. A big improvement is looked for in railway materials consequent upon price reductions and the partial disappearance of Continental competition, but British railways content themselves with placing orders for small tonnages, and apart from a few outstanding orders for Colonial delivery, the market is featureless. Experiments are proceeding at steel works to determine whether the new nickel-silver alloy—which under normal circumstances does not rust or tarnish—can be applied for engineering purposes.

South Yorkshire Coal Trade.—A steady expansion in export business has strengthened prices in the steam coal market. This expansion has more than counterbalanced a diminution in inland consumption, and collieries are able to show more satisfactory order books. Business in gas fuels is falling off. Consumption at gas-producing works is lighter, owing to the reduced requirements of householders. Users are content to draw on reserves and await market developments. Collieries have made big inroads into house coal orders. Both the Metropolitan and the local demand are easier. Activity in blast-furnace coke continues, principally on export account. Selling pressure in slacks is less marked owing to the increased requirements of furnaces. Quotations:—Best branch handpicked, 38*s.* to 39*s.*; Barnsley best Silkstone, 36*s.* to 37*s.*; Derbyshire best brights, 34*s.* 6*d.* to 35*s.* 6*d.*; Derbyshire best house coal, 33*s.* 6*d.* to 34*s.* 6*d.*; Derbyshire best large nuts, 28*s.* to 30*s.*; Derbyshire small nuts, 17*s.* to 19*s.*; Yorkshire hards, 23*s.* to 24*s.*; Derbyshire hards, 21*s.* 6*d.* to 22*s.* 6*d.*; rough slacks, 14*s.* to 15*s.*; nutty slacks, 8*s.* 6*d.* to 10*s.* 6*d.*; smalls, 2*s.* 6*d.* to 6*s.* 6*d.*

LLOYD'S REGISTER AND THE REGISTRO ITALIANO.—An amalgamation was effected not long ago between the two Italian classification institutions hitherto known as the Registro Navale Italiano, and the Veritas Adriatico, in order to establish one Italian registry of shipping under the name of the Registro Italiano. An agreement has been made and ratified between the new Registro Italiano and Lloyd's Register with the object of facilitating the classification of vessels with both societies in the common interests of shipbuilders, shipowners and underwriters. By the system now to be adopted, Italian shipowners will be in a position, while securing the national classification for their vessels, to have also the internationally-recognised classification of Lloyd's Register with as little inconvenience and expense as possible. In order to obviate delays and inconvenience to shipbuilders and shipowners, arrangements will be made, as far as possible, so that the surveys of the two societies shall be held simultaneously; the surveyors of both registers will co-operate in entire harmony and hold jointly the surveys which they will have to carry out. The new agreement only deals with the cases of vessels which hold the dual classification of Lloyd's Register and the Registro Italiano.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—No improvement of any kind can be reported in the ruling conditions of the steel trade in Scotland and the outlook is not very clear at the moment, owing to the unsettlement in the two very important branches of the industrial world—the shipbuilding and the engineering trades. The Minister of Labour has managed to bring both sides together in each dispute and negotiations are proceeding. Should a stoppage in either or both of these trades take place it will have far-reaching results and the steel industry will suffer to a very considerable extent. The general opinion here is that a satisfactory solution can be attained if reason is allowed to prevail, and if each side will look closely into the matter from the standpoint of the other. In the meantime there is no little anxiety in all the allied trades. At the various steel works in this area mills are running slowly and pressure for supplies is quite unknown. Inquiries for varying quantities continue to come to hand, but only small lots are being fixed up. That state would not be so bad if there were even plenty of these, but unfortunately there is only a limited number. So many buyers are still waiting on lower prices—bottom prices they say—that in so doing they may "miss the tide," and be caught. All know what pre-war bottom prices were, but as conditions the world over have so completely changed now no one can tell exactly what the post-war rock bottom prices will be, for the next year or two at any rate. Plates for shipbuilding purposes are almost dead at present and sections are likewise in very poor demand. In the black sheet trade a slightly better tone prevails and business is largely composed of lots of the lighter gauges for markets abroad. Prices all round are without change except that galvanised sheets for export are the turn dearer.

Malleable Iron Trade.—In the West of Scotland malleable iron trade there is still very little doing, and most of the orders are small, with the result that employment is rather irregular. Export is taking up some attention as the home demand is so poor, but even in that direction the lots on offer are not very heavy and have to be cut very keenly to be secured. The current price for "crown" bars is 11*l.* 10*s.* per ton, delivered Glasgow, and for shipment 10*s.* per ton less is being named.

Scottish Pig-Iron Trade.—Little change has taken place in the Scottish pig-iron trade during the past week, and although quotations are the turn easier little fresh business has resulted. The current output is fully ample to meet all demands at present. Foreign trade has not opened out to any extent yet, but there is a feeling that we are on the eve of better times. Scottish hematite is unchanged at 5*l.* 7*s.* 6*d.* per ton, delivered at the steel works, but foundry iron is a shade easier with No. 1 quoted at 5*l.* 2*s.* 6*d.* per ton, and No. 3 at 4*l.* 17*s.* 6*d.* per ton, loaded into trucks at makers' works.

THE INSTITUTION OF RAILWAY SIGNAL ENGINEERS (INCORPORATED).—The officers and council of this Institution for 1922 are as follow: President, Mr. W. C. Acfield, O.B.E., Derby. Past-Presidents, Messrs. A. T. Blackall (Reading), J. Sayers, O.B.E. (Derby), A. Hurst (York), C. H. Ellison (York). Vice-President, Mr. R. J. Insell (Reading). Hon. Secretary, Mr. M. G. Tweedie, G.W.R. Signal Department, 80, Caversham-road, Reading.

PERSONAL.—Mr. Alex. Spencer has been appointed vice-chairman of the Metropolitan-Vickers Electrical Company, Limited, succeeding the late Sir Francis Barker in that position.—Messrs. The Kitson Empire Lighting Company, Limited, Stamford (Lincs.), are adding to their specialities the manufacture of the Kitson-Utley rotary pump (not lamp), as printed in error on page 230 *ante*.—The London offices of the Brightside Foundry and Engineering Company, Limited, Sheffield, have removed from Victoria-street to Chicheley-street, Belvedere-road, S.E. 1.—Mr. R. S. Johnson has been appointed managing director of Cammell Laird and Co.'s Birkenhead Works, in succession to the late Sir George Carter, K.B.E. Prior to joining the company in May, 1920, Mr. Johnson had for many years been connected with the firms of Messrs. Workman, Clark and Co., and Harland and Wolff, Belfast.

THE BRITISH CORPORATION FOR THE SURVEY AND REGISTRY OF SHIPPING.—Addressing the annual meeting of the British Corporation for the Survey and Registry of Shipping held at Glasgow on the 1st inst., the chairman, Mr. Robert Clark, referred to the condition of the shipbuilding industry during the past year and expressed the opinion that in view of the circumstances prevailing the output classed by the Corporation during the year, viz., 281,000 tons, was satisfactory. To this figure must be added a tonnage of 252,000 of vessels already built which have been accepted for classification during the year, so that the total addition to the Register amounts to 533,000 tons. It is now common knowledge that the present abnormal conditions have caused shipbuilding contracts to be cancelled and suspended on an unprecedented scale, but Mr. Clark remarked that work had ceased on only a very small proportion of the 600,000 tons of shipping now on the British Corporation's Register. He also called attention to the number of contracts for new construction and repairs which had been transferred to other countries, and pointed out that this circumstance could not be treated lightly in a country where shipbuilding was of such importance as it was in Great Britain. Past supremacy, he remarked, was of no avail against efficient competition, and to retain the former it was necessary to add to skill and experience the determination to ensure economical production.

NOTICES OF MEETINGS.

THE INSTITUTE OF TRANSPORT.—Monday, March 13, at 5.30 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W. 1, paper on "Railway Problems in China and Australia," by Mr. T. R. Johnson, M.Inst.C.E.

THE ROYAL SANITARY INSTITUTE.—Tuesday, March 14, at 5.30 p.m., at the Institute, London. Discussion on "Central Heating in Relation to Domestic and other Dwellings," to be opened by Professor A. H. Parker, B.A., B.Sc.

THE INSTITUTION OF ELECTRICAL ENGINEERS: SCOTTISH CENTRE.—Tuesday, March 14, at 7 p.m., at the North British Station Hotel, Edinburgh. Paper, "Telephone Line Work in the United States," by Mr. E. S. Byng.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, March 14, at 6.30 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, W.C. 2. Address by the President, Professor J. S. S. Brame, F.I.C., F.C.S.

THE INSTITUTE OF METALS: BIRMINGHAM LOCAL SECTION.—Tuesday, March 14, at 7.30 p.m., in the Chamber of Commerce, New-street. A paper by Mr. D. H. Ingall, M.Sc., A.I.C., on "The Mechanical Properties of Pure Rolled Zinc," will be read and discussed.

THE INSTITUTE OF METALS: SCOTTISH LOCAL SECTION.—Tuesday, March 14, at 7.30 p.m., in the Rooms of the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow. Annual General Meeting. A paper by Mr. R. S. Hutton, D.Sc., on "Motion Study and its Application to Training (with Particular Reference to Metal Polishing)," will be read and discussed.

THE NORTHAMPTON ENGINEERING COLLEGE ENGINEERING SOCIETY.—Wednesday, March 15, at 5.30 p.m. Paper on "Developments in Aeroplane Design," by Mr. R. H. Walmsley.

THE INSTITUTION OF CIVIL ENGINEERS.—Wednesday, March 15, at 6 p.m., Students' Meeting. The first of two Vernon Harcourt Lectures on "The Great Ship-Canals of the World," by Mr. Gerald Fitzgibbon, M.Inst.C.E. Sir Maurice Fitzmaurice, C.M.G., F.R.S., Past-President, will take the chair. Members of all classes are invited to attend these lectures, the second of which will be delivered on March 29.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, March 15, at 7.30 p.m., at 49, Cromwell-road, South Kensington, when a Lecture on "Seiches; and the Effect of Wind and Atmospheric Pressure on Inland Lakes," will be delivered by Dr. E. M. Wedderburn, O.B.E., F.R.S.E. The Chair will be taken by Dr. C. Chree, F.R.S., President.

THE SOCIETY OF GLASS TECHNOLOGY.—Wednesday, March 15, at 2.45 p.m., in St. Thomas' Hall, Stourbridge. The following papers will be read and discussed: (*a*) "Some Notes on the Production of Colourless Glass in Tank Furnaces," by Mr. A. Cousen, B.Sc., A.R.C.S., and Professor W. E. S. Turner, D.Sc.; (*b*) "A Review of the Preliminary Specifications for Refractory Materials used in the Glass Industry," by Mr. W. J. Rees, B.Sc.Tech., F.I.C.

THE ROYAL SOCIETY OF ARTS.—Wednesday, March 15, at 8 p.m., "Certain Aspects of the Problem of Exchange Stabilisation," by Mr. Oswald Toynbee Falk, C.B.E. Sir Robert Molesworth Kindersley, G.B.E., will preside.

THE INSTITUTE OF METALS: LONDON LOCAL SECTION.—Thursday, March 16, at 8 p.m., at the Sir John Cass Technical Institute, Jewry-street, Aldgate. Paper by Mr. D. Hanson, D.Sc., on "Microstructure and Physical Properties of Alloys," will be read and discussed.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, March 16, at 6 p.m., "Phantom Telephone Circuits and Combined Telegraph and Telephone Circuits worked at Audio Frequencies," by Mr. J. G. Hill, Associate Member.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, March 17, at 8 p.m., at Caxton Hall, "Power Factor Improvement," by Mr. G. H. Ayres, A.M.I.Mech.E., A.M.I.E.E.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, March 17, at 6 p.m., at the Institution, Storey's Gate, St. James' Park, S.W. "British and American Locomotive Design and Practice," by P. C. Dewhurst, of Kingston, Jamaica, Member.

THE INSTITUTE OF METALS: SHEFFIELD LOCAL SECTION.—Friday, March 17, at 7.30 p.m., in the Mappin Hall of the University of Sheffield, St. George's-square. A paper by Mr. W. R. Barclay, O.B.E., on "Some Nickel Alloys," will be read and discussed.

THE ROYAL SANITARY INSTITUTE.—Friday, March 17, at 6 p.m., in the Public Hall, Blackburn. Discussion on "The Sanitation of Places of Entertainment," to be opened by Mr. W. Allen Daley M.D., Ph.D., Medical Officer of Health, Blackburn; and "Conversion of Pail Closets," by Mr. A. T. Gooseman, M.Inst.C.E., Borough Engineer. On Saturday, March 18, visits will be made to Messrs. Whitaker's Sanitary Ware Works, the Corporation sewage works, hospital, and refuse destructor, to newly-erected houses and houses in course of erection, cinema theatres, the new public halls, including the Ozonair system of ventilation, tuberculosis dispensary, maternity hospital, &c.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, March 17, at 9 p.m., a discourse will be delivered by Professor A. P. Laurie, M.A., D.Sc., on the subject of "The Pigments and Mediums of the Old Masters." Afternoon Lectures at 3 p.m.: Tuesday, March 14, Sir Arthur Keith, M.D., LL.D., F.R.S., M.R.I., Fullerian Professor of Physiology, R.I., on "Anthropological Problems of the British Empire: Series I.—Racial Problems in Asia and Australasia" (Lecture IV); Thursday, March 16, Mr. P. Chalmers Mitchell, C.B.E., LL.D., D.Sc., F.R.S., Secretary, Zoological Society, on "The Cinema as a Zoological Method" (Lecture I); Saturday, March 18, Sir Ernest Rutherford, LL.D., D.Sc., F.R.S., M.R.I., Professor of Natural Philosophy, R.I., on "Radioactivity" (Lecture III).

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Conditions in the coal trade have shown little alteration during the past week. Generally collieries are fully stemmed on paper, but difficulties have arisen in connection with delay to expected shipping, and this has caused much inconvenience. Despite this sellers refuse to modify quotations, preferring to risk temporary stoppages at the pits rather than lower values. Best large coal is firm at 27*s.* 6*d.*, with seconds at 27*s.* and Monmouthshires from 25*s.* 6*d.* to 27*s.* Smalls, however, are slightly weaker, due to increased outputs. Best steam smalls are obtainable from 19*s.* to 19*s.* 6*d.*, second 18*s.* to 19*s.*, and ordinaries from 16*s.* to 18*s.*, which is 6*d.* to 1*s.* below the prices ruling a week ago. Tenders have been sent in for the Bombay and Baroda Railway inquiry for 170,000 tons of best coal. For two-thirds large and one-third small delivered at Bombay over June-December next tenders are round 46*s.* c.i.f., which, basing the freight at 21*s.*, leaves 27*s.* for the large and 18*s.* for the small, or 6*d.* and 1*s.* 6*d.* below current prices. Exports of coal as cargo from South Wales in the past month totalled 1,788,000 tons, compared with 1,859,000 tons in January and 2,275,000 tons in February, 1913. Though exports last month were double those of the corresponding period of last year they were 71,000 tons less than in January last. Shipments from Cardiff totalled 1,124,000 tons, from Newport 352,000 tons, from Swansea 141,000 tons, from Port Talbot 141,000 tons, and from Llanelly 29,000 tons. Exports to France amounted to 674,000 tons, to Italy 165,000 tons, to South America 222,000 tons, to Spain 130,000 tons, to Portugal 56,000 tons, to Greece 18,000 tons, to British coaling depots 167,000 tons, and to other countries 355,000 tons.

Ship-Repairing Strike.—Ship-repairing work has been dislocated by a stoppage on the part of shipwrights in consequence of a dispute in connection with the employers' application for a reduction in wages. The masters asked for a 25 per cent. reduction in day and piecework rates, but after several conferences modified their request to 12½ per cent., which was accepted in respect to day rates but refused in regard to piecework. The employers, however, laid it down that the reduction must take place in both day and piece rates. As a result, the men at Swansea came out and the stoppage quickly spread to other ports. A joint conference of the employers and men's representatives was followed by a recommendation to the men to return to work on the employers' terms pending further negotiations, but the men refused to re-start. As the shipwrights dock and undock vessels the stoppage has already been responsible for the loss of a number of jobs where vessels required dry docking. One firm alone has lost 10 bottom-painting jobs as a result of the strike.

PELTON WATER WHEELS.—Messrs. Salterns, Limited, Parkstone, have made a departure in connection with their standard size Pelton water turbines by adopting cast-iron machined housing instead of riveted steel housing, and have supplied the first set thus made for driving colliery ventilating fans.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—The fourth annual dinner of this Institution will be held at the Connaught Rooms, Great Queen-street, W.C. 2, on Tuesday, the 21st inst. Tickets can be obtained from Mr. William Sutton, 17, Gracechurch-street, E.C. 3.

THE LATE MR. DRUITT HALPIN.—We regret to record the death, on February 27, at 45, Harvard-road, Gunnersbury, W., after a long illness, of Druitt Halpin, M.Inst.C.E., M.I.Mech.E. He was advanced in years, having become associated with the former Institution in 1871. It was his desire that no record of his engineering work should be published following upon his death.

MECHANICAL LUBRICATORS FOR DIESEL ENGINES.—In a paper read at a recent meeting of the Diesel Engine Users' Association a paper on mechanical lubricators for internal-combustion engines and air compressors was read by Mr. Aubrey B. Smith. The author first referred to the general requirements for these appliances, particularly with regard to reliability, range of adjustment, and accessibility of working parts. He also expressed the opinion that pressure on sight feeds was not detrimental, and mentioned that sight feeds capable of withstanding pressures up to 800 lb. per square inch were now available. A series of diagrams of mechanical lubricators was then shown, and the advantages and disadvantages of each were pointed out. The final lubricator of the series was one in which the pump chamber was kept completely flooded so that the amount of oil delivered depended only on the displacement of the ram and was unaffected by changes in viscosity or by variations in the head of oil in the container. In the discussion which followed the reading of the paper, the speakers generally expressed approval of the principle of sight feed under pressure.

CARRIAGE AND WAGON WORKS OF MESSRS. CAMMELL LAIRD AND CO., LIMITED.

(*For Description, see Page* 292.)

FIG. 3. BENGAL NAGPUR WAGONS IN COURSE OF CONSTRUCTION.

FIG. 4. 12-TON WAGONS FOR THE NEW ZEALAND GOVERNMENT RAILWAYS IN THE ERECTING SHOP.

ENGINEERING.

Offices for Publication and Advertisements 35 and 36, Bedford Street, Strand, London, W.C. 2.

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TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3663 and 8598 GERRARD.

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ADVERTISEMENT RATES.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

All accounts are payable to ENGINEERING, LTD. Cheques should be crossed "The National Provincial and Union Bank of England, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C. 2.

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UNITED STATES: For Subscription, New York: W. H. Wiley, 432, Fourth Avenue. For Advertisements: J. S. Allan, 30, Church-street, New York.

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ENGINEERING.

FRIDAY, MARCH 10, 1922.

THE RAILWAY SITUATION.

IN virtue of an Act passed in 1871 our railways passed under the direct control of the Government at midnight on August 4, 1914, and were only handed back to their proprietors on August 15, 1921. On assuming control, the Government made an exceedingly good bargain with the representatives of the railway companies, under the terms of which the whole of the receipts (with the exception of those classed as "miscellaneous") were paid over to the Government, which for their part agreed to return to the shareholders a sum equal to 97½ per cent. of the equivalent receipts for the year 1913. During the war many industries realised very large profits, but in these the railways had no share. The railwaymen, moreover, though ultimately they received many concessions in the matter of wages and hours, certainly showed little of the callous greed which characterised the action of the engineering unions, which by strikes at Glasgow and Coventry checked the flow of munitions to their hardly-pressed countrymen at the front. With depleted numbers, with plant imperfectly maintained if compared with peace standards, and compelled to do much work under bad lighting conditions, our railwaymen conducted over our lines a traffic of wholly unprecedented magnitude.

In view of the profiteering of the mining and engineering unions and of the rise in prices, it was not in human nature that the railwaymen should refrain from demanding considerable concessions, which as a result have left the companies in a far less prosperous condition than when their undertakings first passed under Government control. At several of the meetings lately held by our chief railway companies, however, appreciation has been expressed at the present attitude of the railway men, who have shown that they recognise the need for economy, and with their good will much of former waste may be prevented, and the high wages now paid may prove fairly earned.

During the period of control the working expenses increased by over 200 per cent. and goods rates have accordingly had to be raised by 110 per cent. and fares by 75 per cent., but the ratio of working expenses to receipts is still far above its 1913 level. Thus, comparing the last four and a-half months of 1921 with the corresponding period of 1913 it appears that the "working ratio" for the Caledonian Railway was 83·5 per cent. instead of 60 per cent. Similarly comparing the whole twelve months the working ratio of the Great Central was 89·33 per cent. in 1922 and 67·86 per cent. in 1913.

Of course, the conditions during the past year have been exceptionally unfavourable. Bad trade and the coal strike occasioned very large traffic decreases both in goods and passengers. The London and North Western line, for example, carried but 83½ million passengers in all, which was 30½ millions fewer than in 1920. Goods fell from 16,800,000 tons to 12,700,000 tons, and corresponding results have been experienced on practically every other line. If trade improves no doubt net receipts may rise, but in this matter the companies are in a somewhat awkward position. If they lower freights they will undoubtedly help trade, but a large increase of tonnage will be necessary to compensate for the reduction in the rates.

In view of the small fraction of the year during which the companies have had possession of their lines, the accounts have been issued in a less amplified form than in 1913, and the chairmen of the various companies, in addressing their shareholders, have for the same reason dealt less with comparative analyses of the figures than has been the case in former normal years. On the other hand, they have had much to say on the Railways Act of 1921, and there have been very notable differences of opinion as to its effects. By this Act the railways of Great Britain are divided into four groups. The largest of these, which will have an aggregate capital of 527,000,000*l.* will consist of the London and North Western, the Midland, the Lancashire and Yorkshire, the North Staffordshire, the Furness Railway Company, the Caledonian, the Glasgow and South Western, and the Highland lines, together with some 26 smaller undertakings. The main members of the Eastern Group will be the Great Eastern, the Great Northern, the Great Central, the North Eastern, the Hull and Barnsley line, the North British Railway and the Great North of Scotland line. The Southern Group is to consist of the London and Brighton line, the South Eastern and Chatham undertaking and the London and South Western Railway. Finally the Western Group will consist of the Great Western and the Welsh railways.

The chairman of the Great Eastern Railway anticipated that the amalgamation would lead to vast economies, but other chairmen have been less enthusiastic, and some have been frankly hostile. Undoubtedly the first effect of an amalgamation should be to effect economies and bring up the standards of the most backward member of the group to that of the best. Though this may be the immediate result, the ultimate effect may not be so favourable. There is probably some limit to the size of an undertaking which can be efficiently managed by one central body. The North Eastern Group will have 7,000 miles of line, extending from London to the North of Scotland and serving communities differing widely in their characteristics. Amalgamation necessarily implies the suppression of independent centres of thought, and the savings to be effected by the standardisations, on which Lord Claude Hamilton laid such stress, may ultimately prove to have been too dearly purchased. Nothing, indeed, is so expensive as premature standardisations which constitute a bar to progress often practically insurmountable. The mileage of the proposed Eastern Group though large, is, of course, much exceeded elsewhere, but mere mileage is but an indifferent gauge of the difficulties of managing a railway undertaking. The Pennsylvania Railroad Company, for example, has but a small mileage compared with some other lines on the North American continent, or, indeed, with the Government railways in South Africa; but its traffic is vastly greater, and it is this which is the crux of the matter. Palæontologists tell us that some of the larger prehistoric creatures endeavoured to compensate for the drawbacks attaching to their size by developing an auxiliary brain centre near their tails, and unless considerable initiative is permitted to the constituents of each railway group, it is far from improbable that the rate of improvement of our services may be slackened. Large bodies are proverbially slow to move, and

even as matters stood it was exceedingly difficult to get a large railway company to make experiments. Not one of them would give an order for a marine steam turbine until others had proved that boats thus fitted were commercially successful. Some of the American railways have tried to overcome this inertia of large bodies by freeing their vice-president from all routine work and entrusting him and his staff with the task of investigating promising proposals.

In the Southern Group of railways none of the partners appear to be wholly contented. The Brighton Company had contemplated proceeding at an early date with its long-projected electrification schemes, but the partners with which it is to be associated willy-nilly, object to further capital commitments being undertaken prior to the consummation of the union. Moreover, each of the proposed partners has its own pet scheme for electrification and objects to having other methods adopted or extended on the systems of its future associates. The Brighton Company have the longest experience in the matter, but the others declare that their proposals are preferable. Incidentally, it may be noted that observations made on the Brighton line show that the conventional rating of engines engaged in shunting operations is too high. It has been conventionally assumed that during its working hours a shunting engine travels 5 miles per hour. By actual observation the figure is found to be but 2·71 miles.

The opinions expressed at the railway meetings on the new method of fixing freight rates have varied as widely as those promulgated on the matter of amalgamation. Up till 1894 the railway companies' power to vary freights was practically unrestricted so long as the charge made was below the legal maximum. By an Act passed in that year, however, a rate once fixed could only be raised after a long fight before the Railway Commissioners. As a consequence, it became impossible for railway companies to try experimental freights, and though the Act was passed at the instance of the traders, the presumption is that they over-reached themselves and have had on the whole to pay higher rates than if the companies had been allowed to retain their former powers. Under the new Act freights are to be fixed by a tribunal, at such a level as to bring in a standard revenue equivalent to that earned in 1913. If rates fixed by the tribunal yield a surplus over this limit the company concerned retains this surplus for that particular year, but a new rate is then to be fixed on the basis that 80 per cent. of the surplus shall be applied to reducing freights, and the remainder retained by the company. Several of the railway chairmen held that this arrangement was not an unfavourable one, but it was strongly denounced by the chairman of the Caledonian Railway Company, who held that it would destroy any desire to cheapen and improve services. Several railway companies have already powers to conduct motor road services, and others are applying for similar privileges. It is pointed out that the opponents of this measure pay only a small fraction of the 50,000,000*l.* annually expended on the roads they use, while the railways have to maintain at their own cost the track on which they have invested some 900,000,000*l.*

The record of the underground tube and 'bus services of London is always of interest. Thanks to the enterprise of these companies, London has by far the best urban services in the world. Whilst the unfortunate inhabitants of Glasgow and Manchester are condemned by their corporations to put up with an unwieldy and out of date tramway service, the Londoner enjoys the benefit of his marvellous 'bus services, which carried no less than 931 million passengers last year. The seating capacity provided by the L.G.O. is now 114,000. Larger 'buses have been put on the road, viz., the K 'bus, which seats 46 passengers, and the S 'bus, with 54. In some respects, no doubt, this increase of size is a drawback. One of the objections to the trams is their very large seating capacity, which necessarily involves an increase of the time spent in stoppages. In view of the increase of wages, however, the change was inevitable, as the same crew can manage a large 'bus as easily as one of lesser capacity. The operations of the London General Omnibus Company now cover 685 miles of road.

During the year an interesting experiment was made. Tram advocates of the type which Abraham Lincoln would have classed as "all the timers" have maintained that the trams would gain an enormous increase of custom if "through" tickets could be issued between sections now disconnected, and the L.C.C. proposed to run to attain this end. However, the 'bus company arranged to do this work for the tramways, and it now appears that in the whole year only 26,000 passengers took advantage of the service. The motor 'bus is now a very reliable vehicle, there having been during the year only one involuntary stop per 6,000 miles run. It also seems to be less dangerous, there having been only 47 fatal accidents in which a 'bus was concerned. A notable point brought out in the companies' report is the very high working ratio of the 'bus services, receipts being 7,684,000*l.* and expenses 6,936,000*l.* Nevertheless, the company has been able to pay the substantial dividend of 8 per cent., free of income tax. It will be seen, however, that the margin between receipts and expenses is so small that it would probably disappear under less able management. The Underground and tube companies, which are its associates in the combine, are much less successful, although the District Railway has for the first time since 1882 paid a dividend on its ordinary stock, the amount being 1 per cent. The average return on the whole of the capital invested in the five associated companies is 3·92 per cent.

THE RATING OF STEEL WORKS.

THE recent judgment of the Scottish Lands Valuation Appeal Court with regard to the valuation for assessment purposes of the eighteen steel works in Lanarkshire deals with many questions of importance to engineers and other manufacturers. No complete detailed valuation of the works had been made since 1901, but the local assessor undertook a general revaluation of them all in 1921, and, as a result, proposed great increases in the valuations. The owners—who are also the occupiers—appealed to the Lands Valuation Committees for the respective wards in which the works are situated. The committee modified the valuation considerably, but both owners and assessor appealed from their decision to the Lands Valuation Appeal Court. The following examples, taken at random, may indicate the difference between the assessor's valuations, those suggested by the owners, and those fixed by the committees :—

—	Assessor's Figures.	Owner's Figures.	Committee's Figures.
	£	£	£
David Colville and Son, Ltd., Motherwell	105,801	27,000	47,454
Lanarkshire Steel Co., Ltd., Flemington, &c.	44,077	13,627	21,043
Smith and McLean, Ltd., Mossend	5,145	1,521	2,099

One of the main questions raised was whether the assessor was right in basing his valuation on the "contractor's principle." He valued the ground, buildings, railways, furnaces, plant and machinery at what he considered their fair capital value. To do this he took the rates prevailing in the year 1914, when conditions were normal, and made allowances for depreciation. Having ascertained the depreciated capital value of the various items, he then applied certain percentages to them, and the totals brought out by this process of calculation were in each case added together and claimed by the assessor to be the annual value of the works for the year 1921–22. The Lands Valuation Committees were of opinion that the assessor was right in applying this method, although they modified in some cases the percentages to be applied to the capital value. The percentages adopted by the assessor and by the committees respectively are given in the table in the next column.

The Committee held that it had been proved that the steelwork industry in Scotland was in a state of great depression, which was due to the upheaval caused by the war and might endure for three or four years; that the Scottish steel works depended to a great extent on the export trade, but that, owing to some extent to the state of international exchange and the economic conditions produced by the war, their competitors on the Continent were able to undersell them both at home and abroad; that at the present time two or three of the Scottish steel works were entirely shut down while others were working on short time; and that the Scottish steel works were less favourably situated for obtaining supplies of iron ore, coke and other materials than many of their English competitors.

Added Percentages Adopted by the Assessor and Committees.

—	Ground.	Buildings.	Railways.	Furnaces	Machinery.
	per cent.	per cent.	per cent.	per cent.	per cent.
Assessor ..	5	7½	7½	10	10
Committees ..	5	7	5	10	7½

The committee could not have allowed a temporary dislocation of trade to affect the valuations, but in view of the seriousness and probable duration of the present depression they made an abatement of 30 per cent. from the annual value of the buildings and other rateable subjects as brought out by the assessor's method of calculation. On appeal the Lands Valuation Appeal Court held that in the circumstances the abatement was justifiable. Lord Salvesen was even prepared to make an abatement of 50 per cent., but Lord Cullen and Lord Hunter considered 30 per cent. sufficient, and as they were in the majority their view prevailed.

Apart from the question of the method of valuation, difficult questions were raised whether certain plant and machinery was heritable within the meaning of the Scottish Lands Valuation Acts, and so liable to be included in the valuation for the purposes of assessment. We may deal briefly with some of the more important of these.

Floor plates consisted of two kinds: (*a*) Large, plain, square, cast-iron plates, resting by their own weight upon the soil inside the building. These were laid down loosely in the works to facilitate the conveyance of materials from the mills to the various machines, the material being either dragged over the steel plates or conveyed in barrows or bogies across them. It was held that they were movable and therefore not rateable. (*b*) Large, square, perforated, iron plates: These were laid on dwarf brick walls or piers specially constructed to receive them. They were apparently regarded as part of the buildings, and therefore rateable.

Travelling-crane rails bolted to uprights consisted of rails resting on brackets which were riveted to the upright steel columns carrying the roofs of the buildings. The rails were merely attached to the brackets by screw bolts with movable nuts. They were held to be movable and not rateable.

There were also difficult questions as to various types of machinery in the works. In England machinery, apart from loose plant, is taken into account by the assessors for the purposes of their valuations, but different rules prevail in Scotland. By the Lands Valuation (Scotland) Amendment Act, 1902, it was enacted that machinery, machines or plant in any building, for producing or transmitting first motive power or for heating or lighting the building (*i.e.*, any building occupied for any trade, business or manufacturing process) should be included in the valuation, but that otherwise the valuation should not include machines, tools or appliances which were only so fixed that they could be removed from their place without the removal of any part of the building.

In some of the works the machinery is driven by current supplied by the Clyde Valley Electrical Power Company, and in some cases this current is converted by means of a motor generator and in others by a rotary converter. The question was whether the converters were machines for producing or transmitting first motive power. If so, they would be rateable. As regards the motor generators, it was held "that the motor portion of the machine was capable of being treated as a separate unit and was heritable (*i.e.*, rateable) up to the shaft forming the connecting link with the generator," but as regards the rotary converters it

was held that it was not possible to separate their functions or split their value, and that they must be treated as wholly rateable.

There was also much controversy as to whether various classes of machines which were bedded on concrete or brick foundations were, in the words of the Statute, only so fixed that they could be removed from their place without the removal of any part of the building. This class of machinery included rolling mills, steam hammers, shearing machines, hot and cold saws, straightening machines, lathes and other types of machine tools. It was contended for the assessor that in cases where the bedplates were grouted into the foundations by cement and where a fillet of cement was left round the bedplate, the machines were rateable; but the committee rejected this contention, and the Appeal Court held that they were right.

The general importance, so far as Scotland is concerned, of the judgment that the depression in the industry is to be taken into account by the assessors is obvious; and although the decisions as regards machinery and plant are not applicable to England at present, they may become so if the present agitation to have the English law of the rating of machinery brought into line with that of Scotland is successful. Lord Cullen's observations when dealing with the subject of the converters are specially noteworthy. He said: "I think it is unfortunate that this court, in common with assessors and valuation committees, should be called on to solve such fine questions relating to electrical machinery on an application of a somewhat crudely-expressed statute which, obviously enough, was not framed in special view of the rapid developments in the use of electricity for motive power which have taken place since its date. The application of the words of the Act to such questions seems to me to involve often what is little more than guess work, and I think it would be very beneficial if the views of the legislature were expressed in an amending statute better adapted to the present state of affairs."

No doubt it would be to the advantage of the judges to have the Act of 1902 amended and made more specific; but we fear that there would be a grave risk of the Scottish manufacturers losing, in an amending Bill, at least some part of the exemptions which the Act of 1902 affords them, and we think it would be better for them to be content with the Act as it stands and as it may be judicially interpreted, than to take the risks involved in further legislation.

RADIO-ACTIVITY.

FOR his course of lectures at the Royal Institution this year, Sir Ernest Rutherford, F.R.S., has chosen the subject of "Radio-activity," a branch of physics which perhaps he has done more than any other individual to elucidate.

In his opening lecture, Professor Rutherford said that during the past twenty-five years there had been extraordinarily fertile developments of physics, none greater, however, than that due to the study of radio-activity. This had disclosed to us a new and unexpected world where we saw passing before our eyes the transformation and disintegration of atoms, a phenomenon which was accompanied by the emission of flying particles and highly penetrative radiations, both manifesting individual concentrations of energy of an intensity previously undreamt of. Moreover, the study had led to the discovery of about 30 new elements of an interesting type, and provided us with a clue for unravelling the structure of the atom. It had added to our knowledge in a variety of fields, provided us in the α particles with the means for probing the structure of the atom, particularly of the lighter elements. It had, moreover, thrown a clear and striking light on those interesting bodies known as isotopes, and had revealed in the inner structure of the atoms unsuspected stores of energy, which were made manifest in the processes of transformation, and it had been shown that in the building up of the atom transfers of energy were made of an order strikingly surpassing those met with in ordinary chemical reactions. The study of radio-activity had also thrown light on geological questions, and on the electrical state of the atmosphere. It had given us new views as to the source of the internal heat of the earth, and on its age. It had brought to light for the first time unstable and divisible atoms, but had also provided us with convincing proofs of the accuracy of the main concepts of the atomic theory.

In this course of lectures, Sir Ernest proceeded, he could not attempt to cover the whole field, but would confine himself to the more interesting and salient facts, in the hope that he might impart to his hearers some of that interest which he had himself felt in the history of a subject to the study of which he had devoted most of his time during the past twenty-five years.

This history presented points of dramatic interest. The detection of radio-activity followed a period of intense scientific activity due to the discovery of X-rays in 1895. All physicists were then anxious to get some idea as to the nature of this new and penetrating radiation. One significant fact, early brought out, was the association of X-rays with

Fig. 1.

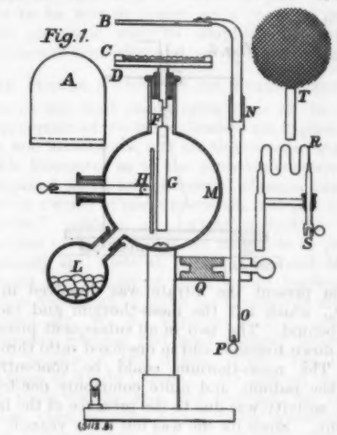
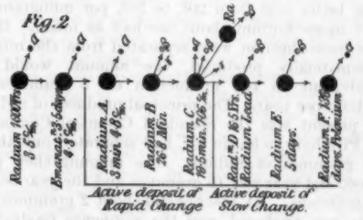


Fig. 2.


Ra C
Radium (100%) 3·5 %
Emanation 3·8 days 4·3 %
Radium A 3 min. 4·8 %
Radium B 26·8 Min.
Radium C 19·5 min. 2·6 %
Rad. D 16 Yrs. Radium Lead
Radium E 5 days.
Radium F 136 days. Polonium
Active deposit of Rapid Change
Active deposit of Slow Change.

phosphorescence. This led to the hypothesis that the generation of the rays was involved with this phosphorescence, and to test this Becquerel exposed photographic plates to the action of different bodies, which had been rendered phosphorescent by exposure to light, and were wrapped up in lightproof paper and allowed to rest on a photographic plate. In the course of this work Becquerel recollected that he had prepared some twelve years before crystals of uranium potassium sulphate which also had the property of phosphorescing. He obtained these and, using them as described, found that in 24 hours he got an impression on the plate. Thinking this might be due to phosphorescence, he repeated the experiment without previously exposing the crystals to light, and still got the same result as before. This proved that ordinary phosphorescence had nothing to do with the matter, and that we were confronted with a special kind of radiation. Becquerel subsequently examined the peculiarities of this radiation. Certain minor errors were naturally made; but he successfully demonstrated all the essential properties, proving that uranium's powers of affecting a photographic plate were independent of a prior exposure to light and were possessed by all compounds of uranium. It was also found that the radiation had the power of causing electrified bodies exposed to it to lose their charge. This property Sir Ernest Rutherford demonstrated by placing a little uranium oxide on the top plate of a Zeleny electroscope, an instrument which is illustrated in Fig. 1. It consists essentially of a gold leaf G suspended from the top plate D of the instrument, and given a quarter twist so that it presents its edge to the side plate H, which is kept charged to a constant potential. The gold leaf being attracted to this plate, picks up a charge there and is repelled. If the charge is able to leak off from the top plate the gold leaf is again attracted to the side plate and acquires another charge. Hence the rate of oscillation of the gold leaf provides a measure of the rate of leakage of electricity, and this rate was, he showed, enormously increased when the uranium oxide was placed on the top plate. Owing to the presence of a good deal of radium on the lecture table, there was, during the demonstration of this experiment, some leakage even when no radio-active material was placed on the top plate.

A procedure similar in principle to the foregoing was, he proceeded, adopted by Madame Curie to whom the next development was due. She showed by measurement of the electrical effects produced, that not merely did all compounds of uranium show radio-activity, but that the effect was strictly proportional to the amount of uranium present, and was accordingly a property of the uranium atom. She next found that a sample of pitchblende containing 70 per cent. of uranium was four to five times as active as if it were wholly uranium. Since radio-activity had been proved to be an atomic property, it followed that the pitchblende contained some other radio-active substance besides uranium. Its isolation was then a simple problem. The pitchblende was put through a course of systematic analysis of the usual type. After solution a precipitate was obtained with H_2S which proved to be very active, and the active agent in this was named polonium by Madame Curie in honour of her native country. Proceeding with her analytical processes, Madame Curie found that when the barium present in the solutions obtained from pitchblende was precipitated, it showed exceptional radio-activity. It was found possible to concentrate the active agent associated with the barium by fractional crystallisations, and thus radium was ultimately obtained. This element was, Sir Ernest proceeded, precipitated from solutions with any barium also present, but could be isolated from the latter and obtained pure. Radium was found to have definite chemical properties, and a characteristic spectrum. Its atomic weight was 226, that of uranium being 238. The actual metal had, he said, now been reduced from its salts by electrolysis, and was found to be a highly oxidisable body melting at about 700 deg. C.

It might be asked why radium had been so markedly singled out from the other radio-active constituents of pitchblende, many of which were of much greater activity? The answer was in part that radium was readily purified and had a fairly long life, but the main point was that radium was the parent of a very interesting and very vigorous family of radio-active elements, as indicated in Fig. 2. The last two members of the highly active group gave out very powerful γ-rays, and were accordingly much used for therapeutic purposes. With radio-active minerals of the uranium group in a state of equilibrium it was evident that the quantity present of each member of the family must be a definite proportion of that of the uranium from which they were all derived. Thus there was in such cases 3·4 parts of radium present to 10,000,000 parts of uranium. This was an exceedingly small amount. For example, if the amount of uranium present in a piece of pitchblende were represented by a length of 350 miles, the quantity of radium also there would be represented by a length of 4 in. and the amount of polonium by $\frac{1}{1,000}$ in. As for the other radio-active constituents, the amount was almost immeasurably small. Thus on the same scale as above the quantity of RaC, which was the main active principle, would be represented by one ten-millionth of an inch. The photographic effects produced by uranium were feeble. A strong X-ray tube would produce as great an effect in one second or 2 seconds as a piece of uranium would in three weeks, and as much as radium would do in 5 seconds.

To illustrate the phosphorescent effects due to the radiations, the lecturer employed a tube enclosed on the end of which was some of the emanation;

the activity of this was, he said, equivalent to that of 100 milligrammes of radium. Various screens exposed to this tube phosphoresced brightly, the best being that coated with zinc-sulphide.

Thorium, like radium, also, Sir Ernest said, showed radio-activity, but the effect was only about one-fourth as great. Nevertheless, from the point of view of getting active preparations it was nearly as important as radium. As for the minerals from which these radio-active bodies were obtained there were important differences in their constitution, depending on the age of the rocks; as is clearly shown in the subjoined table, where a typical primary uraninite from Glastonbury, about 1,000,000,000 years old, is compared with a secondary uraninite (pitchblende) from Saxony of relatively recent origin.

Table giving Composition of Primary Uraninite from Glastonbury and Secondary Uraninite from Saxony.

	No. 1. Glastonbury, Conn.	No. 2. Johanngeorgenstadt, Saxony.
Specific gravity ...	9·59	6·89
UO_3	26·48	60·05
UO_2	57·43	22·33
ThO_2	9·79	—
CeO_2	0·25	—
La_2O_3	0·13	—
Y_2O_3	0·20	—
PbO	3·26	6·39
CaO	0·08	1·00
He	und.	und.
H_2O	0·61	3·17
Fe_2O_3	0·40	0·21
SiO_2	0·25	0·50
Al_2O_3	—	0·20
Bi_2O_3	—	0·75
CuO	—	0·17
MnO	—	0·09
MgO	—	0·17
Na_2O	—	0·31
P_2O_5	—	0·06
SO_3	—	0·19
As_2O_3	—	2·34
Insoluble	0·70	—

It will be seen from this table that the secondary uraninite contains a much greater variety of substances, and it had been suggested accordingly that when the Creator got tired of making new elements he lumped the residue all together into pitchblende.

At the outset, radium was obtained from the pitchblende of Joachimstal, in Bohemia, where the present production was about 2 grammes a year. A certain amount had also been obtained from the pitchblende found in the Cornish tin mine dumps, but the greater part was now derived from carnotite, a mineral found impregnating certain sandstones in Colorado, Utah and also in Australia. This mineral was a vanadate of uranium and potassium, and contained 42 per cent. to 51 per cent. of the former metal. It had the advantage over pitchblende of being much more readily soluble. To get 1 ton of sandstone containing carnotite, about 10 tons of rock had to be mined, and the best selected by hand-picking. Even then the material thus selected for further treatment contained only 1 per cent. of uranium, so that the ore was a very low-grade one, no less than 500 tons of it being required for a yield of 1 gramme of radium.

Professor Rutherford said that he was indebted for the foregoing particulars to Dr. Vial, of the Standard Chemical Company, Pittsburg. The carnotite was dissolved in HCl and the radium and barium precipitated together as sulphate. The total amount of these mixed sulphates derived from 500 tons of the original rock was from 1,000 lb. to 1,500 lb. The radium was next separated from the barium by fractional crystallisation of the bromides. The first 55 per cent. of the barium bromide crystallising out of the solution carried down with it 97 per cent. of the radium present so that at each repetition of the process, the proportion of radium present was nearly doubled, and it could in fact be obtained quite pure, but the commercial article generally contained 97 per cent. of the radium salt. It was usually sold as the bromide or as the chloride, but sometimes when required to be insoluble, as the sulphate.

Coming next to thorium, it would be seen on referring to Fig. 3 that the really active principle was meso-thorium, which was chemically identical with radium, being an isotope of that element, but having very different radio-active properties. Its activity fell to half value in about six years. The result of the transformation of meso-thorium II was radio-thorium, of which the activity fell to half value in two years. From any solution in which meso-thorium and radium were present the two separated out together. Thorium nitrate was produced commercially to the extent of some 300,000 kg. per year, almost the whole of which was obtained from the monazite sands found in Brazil and on some of the shores of the United States. To separate out the meso-thorium and

Fig. 3.

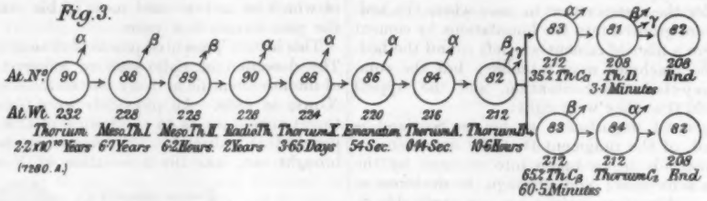


Fig. 4.

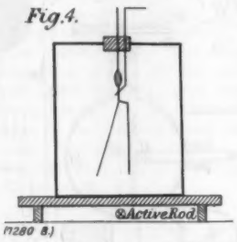
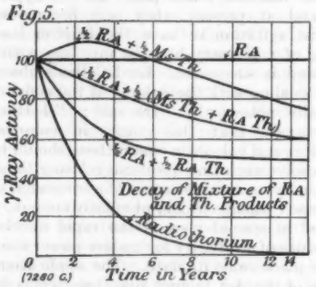


Fig. 5.



radium present the nitrate was dissolved in hot H_2SO_4, which left the meso-thorium and radium salts behind. The two in all subsequent processes came down together and in one fixed ratio throughout. The meso-thorium could be concentrated with the radium, and quite commonly one-fourth of the activity was due to the presence of the latter element. Since its life was but a few years it was, however, intrinsically less valuable than radium. The latter cost from 20*l.* to 30*l.* per milligramme, and meso-thorium about one-half as much. If all the meso-thorium were separated from the nitrate commercially produced, the amount would be equivalent to the production of 5 grammes of radium per year. The principal producer of radium at present was the Standard Chemical Company, of Pittsburg, who, in all, had separated out about 85 grammes of radium. The amount they produced last year was 16 grammes and the year before 18 grammes. At Joachimstal about 2 grammes per year was produced, and the aggregate production in Europe from the outset has not exceeded 40 grammes. Taking all producers into account the total amount of radium so far obtained was about 160 grammes, of which much the greater part was used in the hospitals. Only about 5 grammes had gone to physicists and chemists for research purposes.

Sir Ernest next dealt with the testing of radium. A committee, of which he was chairman, was appointed to consider this matter in 1912. A primary standard of 22 milligrammes of radium chloride was prepared by Madame Curie, the cost being defrayed by Dr. and Mrs. Beilby. Secondary standards calibrated by comparison with this were next prepared at Vienna and distributed to the various national laboratories, whilst the primary standard was preserved at the Bureau of Arts et Metiers, near Paris.

By the use of these standards the amount of radium in a sample could be determined to 1 part in 200 without the necessity of opening the tube, in which it was sealed. For this end the electroscope represented in Fig. 4 was used. After charging the electroscope the sample was placed below it as indicated by the words "active rod" in the figure and the rate of loss of charge measured by timing the falling in of the gold leaf of the instrument and comparing this with the rate observed when a standard sample was similarly treated. Both meso-thorium and radium gave rise to very penetrating radiations, and these only were employed in making the test, the softer radiations also emitted being screened off by lead plates, 1 cm. thick.

Adulteration of a sample of radium with meso-thorium could be detected by observing the rate of decay of the activity. The fall in activity with lapse of time, of various mixtures of radium and thorium was represented by the curves reproduced in Fig. 5. The meso-thorium had a life of only a few years, and hence the rate of decay was much more rapid than when radium alone was present, though as shown in the figure with certain mixtures the activity was at first a little greater than if radium only were present. It was thus possible in the course of a few months to determine whether or no a sample had been adulterated. Another mode of detection depended on the fact that the alpha particles from radio-thorium had a little longer range than those emitted by radium.

NOTES.

THE MACHINE TOOL TRADES ASSOCIATION.

IT is common knowledge that the machine tool trades have had to face more than usually adverse conditions during the last twelve months. The general slackening of business has affected them in common with others, while the conditions imposed due to the large and continuous sales of surplus machine tools by the Disposals Board have hardly had a parallel in connection with any other industry. It appears from the report of the Machine Tool Trades Association, which was presented at the annual meeting on Wednesday, that representations have been made to the Disposals Board in connection with this point, and the suggestion made that the sales might be regulated with reference to the conditions of the industry as regards employment. So far, however, no agreement has been reached on the matter. The report in general shows that the activities of the association have been well maintained, and a large number of matters on which action has been taken are dealt with. Apparently members have not in the past fully realised the assistance which the association can give in dealing with foreign Governments, income tax authorities, insurance companies, &c., and a number of examples are quoted in which firms have been helped with the advise, or authority, of the association. An interesting section of the report deals with employers' liability and workmen's compensation insurance. It appears that on the average members are paying 1*l.* for every 7*s.* 4*d.* received back in premiums. The report of the Departmental Committee on Workmen's Compensation expresses the opinion that management expenses, profits, &c., ought not to exceed 30 per cent. of the premium income, leaving 70 per cent. for the payment of benefits. This means that 14*s.* out of every 1*l.* should be available for payment of claims. It also appears that employers generally receive 9*s.* 7*d.* for provision of benefits out of every 1*l.* paid, as compared with the 7*s.* 4*d.* received by machine tool makers. The report is able to announce that as a result of its efforts in connection with this matter the insurance rates of many members

have been considerably reduced. Other important matters dealt with in the report are railway rates, shipping rates, tariffs, &c. It is also announced that as a result of representations to the Chancellor of the Exchequer, entertainments tax will not be payable in respect of the next exhibition organised by the association. The annual dinner was held on the evening of Wednesday last, Sir Alfred Herbert, the President, being in the chair, and in the course of the evening several references were naturally made to the great difficulties through which the machine tool industry was passing. In the course of his speech proposing the toast of the Association, Sir Howard Frank stated that the Disposal Board had already sold 60,000 machine tools, which was roughly 90 per cent. of the stock with which they had to deal.

The New Electricity Bill.

The new Bill dealing with electricity supply, the second reading of which was completed in the House of Lords on Wednesday, is a necessary outcome of and appendage to the existing law. Joint Electricity Authorities can be set up under the Act of 1919, and some are in process of being set up. The authorities have, however, no financial powers, and the purpose of the new Bill is briefly to enable them to borrow money, or to enable municipal authorities to lend them money. Any proposals which are likely to lead to large borrowings by authorities backed by the rates are naturally and rightly the subject of close attention at the present time, and the Bill is not likely to get through Parliament without opposition being manifested. The Bill is, however, really a necessity if a considerable number of the clauses of the Act of 1919 are not to become dead letters. The idea of a Joint Authority running the electricity supply of Greater London and at the same time having no financial powers at all is ridiculous. Opposition to this Bill, except possibly on minor points, is opposition to the control of electricity supply by public bodies. Such opposition is understandable, and much may be said for it, but matters have now moved beyond the stage at which such opposition has any relation to practical measures. The Joint Electricity Authorities created under the Electricity Act of 1919 are semi-public bodies, and members may represent either municipalities or private companies. The authorities cannot operate without funds, and their only possible source of funds at the present time is the private companies from which they are partly formed. As there does not appear to be any reason to anticipaté that private companies are likely to place their funds in the hands of a body over which they have not full control, some further method of financing the joint authorities must be provided. This is done by the new Bill, and it, or something equivalent to it, is necessary if the Act of 1919 is to work.

Rules for Tubulous or Water-Tube Boilers.

It will be remembered that some time ago the British Marine Engineering Design and Construction Committee brought out a set of approved standard conditions for the design and construction of marine boilers and shafting. An account was given in our issue of December 17, 1920 (page 813) of this committee's excellent work in reducing to order the many sets of rules extant to which designers have had to work. The committee's first report was divided into four parts, dealing respectively with main boilers of the cylindrical type, with auxiliary and special boilers, steam, feed and other pipes, and shafting for marine engines. We mentioned at the time of noticing this publication that the work was to be continued with a view to covering conditions for tubulous or water-tube boilers in the same way, and the committee's report on these have now been issued, as a separate brochure. In this Part V, the matter is dealt with on lines similar to those adopted in the preceding four parts. The subject is divided into sections, of which the first is concerned with general design and materials. Section II is devoted to the subject of tubes; Section III to the construction of water-tube boilers; while Section IV deals with boiler mountings. This pamphlet which, in view of the popularity of water-tube boilers will doubtless prove as serviceable as the earlier set of rules, may be obtained from Mr. A. Dansie, secretary of the British Marine Engineering Design and Construction Committee, 5, Adelphi-terrace, W. C. 2, at the cost of 2*s.* 6*d.* The standard conditions thus set out should carry very considerable weight, as the committee, as is well known, is a very representative one. Under the chairmanship of Mr. A. E. Seaton, it includes representatives of the Institution of Naval Architects, the Institution of Engineers and Shipbuilders in Scotland, the North-East Coast Institution of Engineers and Shipbuilders, the Institute of Marine Engineers, and the Liverpool Engineering Society. The three registration societies of Lloyd's, the British Corporation and the Bureau Veritas also have representatives on the committee, which has had the benefit of the assistance of some co-opted members in addition, and of Mr. T. Carlton, of the Board of Trade, though not officially sitting as a representative of that department. The institution of the committee, as we noted at the time, marked a distinct advance, and its effort to place requirements to be met in design on a common ground should go some way to simplify and improve conditions of tendering and, so we hope, of trade.

The Proper Functions of Trade Unions.

One of the most encouraging signs of the times is that certain of the labour leaders are beginning to think and investigate, and are thus recognising that reliable forecastes as to the probable consequences of proposed social and industrial changes must be based on a study of past experience, and not on the "Fabian" system of logical deduction from unverified premises, which we may note in passing apparently still finds an adherent in Lord Milner. Amongst the boldest of these labour leaders who are thus venturing to think for themselves must be reckoned Mr. W. A. Appleton, C.B.E., who on Wednesday evening last read a paper before the Royal Society of Arts dealing with "The Proper Functions of Trade Unions." He pointed out that when trade unions were first founded, the leaders insisted that religious and political questions, on which history shows that general agreements are impossible, lay outside the scope of trade union activities, and he deprecated the demands recently made, that the powers of the trade unions should be devoted to furthering the concession of Home Rule in India or to maintaining despotism in Russia. Mr. Appleton is, moreover, no believer in the sympathetic strike. It is one thing, as he points out, to strike against a bad employer—and even a strike against a good one for the purpose of coercing a bad employer may, he says, be condoned as permissible tactics—but a general strike alienates public opinion, which in any free country is the decisive factor in any serious industrial dispute. It may be added that experience has shown that a general strike has never been successful in the past, and, in fact. cannot be unless it developes into a successful revolution. If protected from violence the ordinary public can carry on the public services adequately even if at the outset somewhat inefficiently. In fact there have been instances in which within a short time the volunteers who have come to the rescue of the general public, have bettered the record of the regular staff. In Mr. Appleton's view a trade union should be an organisation for the betterment of wages, hours and working conditions of persons engaged on similar materials, using similar tools, and producing similar results. Their proper functions thus embrace every problem connected with, or arising out of, employment and unemployment, and out of trade and commerce, in so far as these affect employment. Amongst these problems are those affecting wages, hours, conditions under which employment is provided, safeguards against industrial disease and accident compensation where disease or accident results, and provision against unemployment. With regard to wages he feels that though this reward is sometimes inadequate, yet the monetary return does not represent the whole of the reward. Like Kipling's hero, McAndrews, he finds an important part of the return in the consciousness of work well done.

Ancient and Modern Dyeing.

The two interesting lectures which Professor Arthur G. Perkin, F.R.S., of Leeds, recently delivered at the Royal Institution, cannot but enhance our admiration for the beautiful achievements of ancient dyers and their descendants in China, India and other countries where primitive methods are still being practised. Nature has furnished us with very few "substantive or direct" colouring matters which will permanently dye the fibre steeped in them, and strangely enough, there is no natural green colouring matter. We can "stain" the fibre and dry it without washing. To dye the fibre we have to prepare it in some way. Every dyer knows now that if "mordanting" with alum or ferrous sulphate will not yield the desired shade, he may try tin, copper or chromium salts, and alkaline or acid baths. But alkalis and bases, metallic oxides, salts of tin and aluminium, oxidation and reduction in the vat, and the influence of the purity of chemicals, now so much insisted upon, had, and have, no meaning for the native worker at all. And yet indigo vat dyeing was practised 3,500 B.C., and scientists, though amazingly proficient in varying their processes and effects, are not agreed what dyeing really signifies. Even the nature of mordanting was not understood half a century ago. Mordanting consists in fixing on the material certain metallic oxides or compounds which combine with the colouring matter and form a "lake." The ancients made use of oil emulsions, extracted dyes from plants and insects and obtained the Tyrian purple from the pus of a snail, of which 12,000 yielded to Friedländer 1·4 grammes of the dibromo-indigotin, the chief colouring matter. The mauve of Sir William Perkin—Professor A. G. Perkin is one of his sons—followed by the discovery of other dyes, brighter and faster than most natural dyes, drove the latter out of the field. They had a temporary boom again during the war. But the handsome safflower red, the turmeric yellow and other natural fleeting colours have vanished. Logwood, fustic and Persian berries retain a certain use; madder, the natural source of alizarme, is practically extinct. Indigo, most renowned as fastest dye, has now been surpassed in fastness by artificial vat dyes of the indigo (hydron) and anthraquinone types. Some of these are so fast indeed that they will survive destruction of the fibre. The modern acid mordant dyes are azo-colours, substantive to wool, in which the colour is brought out after dyeing by boiling with chromates, all in a single bath operation. In economical calico printing (striped effects) bleaching follows dyeing, instead of preceding it; that is only possible with very fast dyes. Inexpensive sulphide dyes, fast except in brown and yellow shades, are gaining in favour. Aniline black and resorcin blue, &c., are synthetised in the fibre, and though dyeing is not quite so simple as the demonstrations by Professor Perkin and his assistant, Mr. King, made it appear, and the researches underlying it are highly complex, progress is still rapid, even in the troublesome problems of dyeing artificial acetyl silk.

THE INSTITUTE OF METALS.

The fourteenth annual general meeting of the Institute of Metals was opened last Wednesday morning in the Hall of the Institution of Mechanical Engineers, Sir George Goodwin, the retiring President, occupying the chair during the opening proceedings.

Report of the Council.

In their annual report for the year ending December 31, 1921, the Council are pleased to note that, notwithstanding the period of trade depression through which the world has been passing, the membership has increased during the year from 1,298 to 1,410. Such an increase, during a year of unparalleled difficulty, points to the fact that makers and users of non-ferrous metals and alloys are more than ever ready to take advantage of the scientific information obtainable through association with the Institute.

Corrosion Research.

Research has been continued on the factors which initiate and accelerate the corrosion of copper, zinc, nickel and their alloys. The work of the Aluminium Corrosion Committee has been largely devoted to the preparation and testing of protective coatings of molybdenum compounds and aluminium hydroxide on aluminium and certain light alloys. This investigation is still in progress. Work has

also been directed towards ascertaining the factors which initiate and accelerate corrosive attack on commercially pure aluminium. Certain sections of the research rendered it desirable to obtain some method for the direct estimation of aluminium, and a considerable amount of time has been devoted to the testing and comparing of possible methods.

BEILBY PRIZE RESEARCH.

The work on the solidification of metals has been interrupted by many causes, especially by the large influx of students and by the departure of research workers to take up other duties. The mass of material which has been accumulated during the past two years is now being arranged, and experiments are being made to clear up the points which were left in doubt.

THE JOURNAL OF THE INSTITUTE.

Two volumes, XXV and XXVI, were issued during the year, the latter, covering 760 pages, being the largest ever issued by the Institute. The experiment, made in 1920, of issuing separate reprints of the Abstracts, met with success, and has been continued. The general index being prepared will cover volumes I to XXV. It will be issued as a separate volume at 25*s.* net, or 12*s.* 6*d.* to members and students.

LOCAL SECTIONS.

Good work has been done by the Local Sections during the year, a large number of useful papers being contributed. Certain of the papers were printed in the Journal. Rules have been approved for a new Section in Newcastle-on-Tyne, to be known as the North-East Coast Local Section, of which the Hon. Sir Charles Parsons is Chairman, and Mr. H. M. Duncan, Heaton Works, Newcastle-on-Tyne, is Hon. Local Secretary. It is desired by the Council that every member and student member living within a radius of fifty miles of any Local Section Centre should send his or her name to the Honorary Local Secretary for enrolment as a Local Section member. Only those persons so enrolled receive notices of Local Section meetings.

REPORT OF THE HON. TREASURER.

The Hon. Treasurer, Mr. A. E. Seaton, said he was pleased to report that the financial position of the Institute as at June 30, 1921, was satisfactory, notwithstanding the very great increases in expenditure, which the Institute had been able to meet by the increase in subscriptions. The total amount of the subscriptions was 4,030*l.*, as against 2,892*l.* for the preceding year. The sales of the Journal were good, but considerably under those of the preceding year, being 794*l.* as against 1,100*l.* The miscellaneous receipts were 101*l.*, as against 17*l.*, so that the reduction in these two items together amounted to a little over 200*l.* The cost of production of the two volumes for the year increased from 1,615*l.* to 2,303*l.*, which latter figure represented more than half the subscription income. The salaries were nearly 50 per cent. over those of the preceding year, and the subscriptions, grants and fees were 104*l.*, as against 15*l.* 15*s.*, the large increase being due almost entirely to grants to the various Local Sections. Printing and stationery were also high, as was anticipated, being 457*l.* as against 322*l.* It is expected that these items will amount to considerably less in the current year. Repairs and renewals had also necessarily been high; many of them were postponed during the war. The Institute still had 2,971*l.* invested, and it is hoped that this item may be increased.

On the motion of Sir George Goodwin, the Hon. Treasurer was accorded the thanks of the meeting for his report and the hard work which it involved.

THE NEW PRESIDENT.

Mr. Leonard Sumner, O.B.E., M.Sc., was then inducted into the chair, and before he delivered his presidential address, the retiring president, Sir George Goodwin, on the motion of Professor Turner, seconded by Mr. R. T. Rolfe, was thanked by acclamation for the admirable way in which he had directed the affairs of the Institute during his term of office.

In acknowledging the thanks of the meeting, Sir George expressed the pleasure he had always felt in witnessing the keen interest which all members took in their science; it had also been a great satisfaction to him to see that their science had received practical applications. He associated as an engineer with other institutions and was proud to see the prominent part which the work of the Institute of Metals played in the work covered by those other Institutions. That was going not only to continue, but also to increase, and, well as it had done in the past, the Institute was going to have a still greater future.

In the course of his address, Mr. Sumner stated he was interested in the manufacturing branch of the non-ferrous metal industry, but, through the force of circumstances, he had gravitated largely to the commercial side of the industry. The prosperity of the country depended entirely on the prosperity of its industries, trades and commerce. In the same way, the prosperity and, therefore, the utility and activity of the Institute were dependent upon the state of trade of the country, and more particularly upon the prosperity of the non-ferrous metals industry. As a manufacturer, he was most willing to bear testimony to the very great benefit which that industry had derived from the Institute; in fact, the fortunes of the industry and those of the Institute were closely interlocked, and it was of vital necessity to the great majority of members that the proved usefulness of the Institute should be not only maintained, but possibly increased.

After referring to the work carried out by a number of members during the war and to the rapid growth in membership, Mr. Sumner stated that the most gratifying increase was the one among the student members; in 1916, the student members numbered 6, to-day they numbered 116. These young men were those upon whom the scientific and industrial progress of the country would largely depend in the future.

Sir Gerard Muntz, a few years ago, had expressed regret at the unwillingness which existed between manufacturers to interchange ideas and experience. To-day, Mr. Sumner said, that state of mutual antagonism and mistrust no longer existed, at all events in the part of the industry with which he was most intimately connected, the war itself having finally destroyed all prejudice, for during the war every manufacturer desired to do all he could for his country in its hour of need, and one and all both gave and received information. There was, further, a feeling that manufacturers did not contribute their quantum to the Institute from the point of view of membership, and he appealed to the manufacturers who were members to get others to join. It had also been said that manufacturers did not contribute papers nor take part in discussions as they should (see ENGINEERING, vol. cxii, page 483); in this connection he would state that manufacturers were generally placed in a difficult situation, in that they had to consider the commercial aspect very seriously, and if at times they appeared reluctant in coming forward with papers and contributions, he would ask the Institute to bear in mind the difficulties of their position.

In the matter of specifications, drawn up by responsible bodies, Mr. Sumner noted with satisfaction that the manufacturer was now enabled to use his discretion and knowledge as to the kind of raw material he should employ, provided he produced an article which would conform to the required conditions. Bearing upon this point in his address, he expressed the wish that metal merchants and brokers should become more actively interested in the work of the Institute than they were now, so that it could be impressed upon them how vastly important it was for them to be able to give manufacturers every possible information concerning the particularities of the metals they had on hand to sell.

Mr. Sumner emphasised the necessity there was for all our universities and colleges, which give degrees in engineering, insisting upon the point that one of the subjects which the student must qualify in, if he is to get his degree, is metallurgy. The students, also, who were expecting to occupy technical positions in works must be afforded opportunities to have works practice in conjunction with their educational training. He (the speaker) was sometimes inclined to think that British teachers were probably too prone to show too great an interest in the brilliant student to the possible neglect of the student who was not so clever, they seeming in this to overlook the fact that industry required many sound and able men and a few brilliant ones only.

In concluding his address, Mr. Sumner said that at the end of 1914, there were 20 members domiciled in our dominions overseas and 83 resident in foreign countries. In 1921, the figures were 46 and 204 respectively, an increase of 26 in the Dominions and 121 in foreign countries. Steps, he thought, should be taken to increase membership amongst our own kith and kin. The future of the non-ferrous metals industry in Great Britain was very uncertain. At the Washington Conference it was agreed that there should be a limitation of navies; that decision affected the Institute's industry vitally, for the navies of the world were very heavy consumers of non-ferrous metals. The best brains, commercial and technical, were required now and in the immediate future to extricate the industry from the slough into which it had fallen—temporarily only, he firmly believed—and in that task, difficult as it would be, he was convinced that the Institute would take a strong and prominent lead.

Dr. Carpenter, after referring to the long period during which he had been acquainted and had been in constant communication with Mr. Sumner, and complimenting the Institute on having him as a president, called the attention of the meeting to various parts of the address where Mr. Sumner mentioned his (Dr. Carpenter's) name in connection with the training of students, and emphasised the difficulty of this training. He (the speaker) was not going to discuss the address, but would not let the matter drop, and suggested that in the near future an exchange of views on the subject be brought about. Researchers and analysts lived mostly in laboratories; a student preparing to be a works manager was most difficult to train in a college, and his real test came when he entered the works. Dr. Carpenter asked Mr. Sumner to take the matter up in order to see whether a new course could not be introduced and training modified so as to prepare men for the other type of work distinct from research and laboratory work. He quite agreed that it was desirable for engineers to have a knowledge of metallurgy, and for metallurgists to have a knowledge of engineering; this course was adopted at the Imperial College. He moved a hearty vote of thanks to the new president for his address.

In seconding, Sir Gerard Muntz said he was pleased to see another manufacturer in the chair; other presidents of late had been men of science and well-known engineers, and it was now the turn of actual manufacturers to direct their affairs. Their new president had a thorough knowledge of non-ferrous metallurgy. He (Sir Gerard) expressed the hope that he would give later a paper on the training of students for actual works practice, or arrange for such a paper to be given during his term of office. He had great pleasure in seconding the motion, which was carried by acclamation.

NOTES ON THE CORROSION AND PROTECTION OF CONDENSER TUBES.

The first paper taken at the meeting on Wednesday morning was the one having the above title, by Dr. G. D. Bengough, and dealing with ten years' scientific investigation of the problem. The notes cover 30 pages, and review in detail the causes of corrosion due to the tubes themselves, those due to external conditions, and the various means of protection. These notes are of an eminently practical nature and will be found most useful by both the tube makers and tube users, notably, among the latter, the shipbuilding and shipping companies. They have been available for some weeks, and form part of the Institute's proceedings, vol. xxvi, pages 433 to 463.

In presenting these notes of the Corrosion Research Committee, Dr. Bengough emphasized that they were destined for practical use rather than for scientists. For the latter, more particularly, further evidence would be put forward later. He called special attention to many of the difficulties which surrounded the research work owing to the very complicated chemical and electro-chemical reactions varying with the practical conditions as regards time, temperature,

&c., under which the work was being carried out. He added as an illustration of the time question that tubes occasionally lasted over twelve years before complete perforation by local or general leakage took place. The question as to whether tubes would show re-deposition of copper was very important, tinned metals had a very great effect on dezincification, and arsenic had the most perceptible effect. He suggested that the total impurity should not exceed 0·4 per cent.; he referred to the British Engineering Standard specification, and failed to see what the Association had in mind when they suggested a figure of 0·7 per cent. for the impurity. The problem of the Research Committee was to find out which was the best tube in adverse conditions; the Committee was looked to for arriving at that best tube, and therefore it cut down the impurities to the lowest possible figure for a tube destined to serve in such adverse conditions. In the figure of 0·4 per cent., iron could not enter for more than 0·1 per cent., and under those conditions, dezincification, the Committee thought, would be stopped to a large extent. The Standard specification contained a clause to the effect that the tube had to withstand an internal water pressure of 600 lb. to the square inch, whilst the Admiralty required 1,000 lb. without the tube showing indications of weeping. He (the speaker) was inclined to adopt the latter figure, for he found that corrosion passed first in the inter-crystalline boundary and down the twinning planes, and liquid could penetrate largely in the same place in the metal. Dr. Bengough illustrated this point by lantern slides, showing how deep the action could penetrate down in the metal in the inter-crystalline passage. In this connection, a high internal water pressure was a better test than a lower.

Sir Gerard Muntz, who opened the discussion, congratulated Dr. Bengough on the practical nature of his notes, which enabled the general public to know the class of work that was being carried out and the conclusions arrived at. He (the speaker) found that the notes advocated the use under all ordinary circumstances of tubes and ferrules of Admiralty brass 70 : 29 : 1, as a rule, but had quoted against this rule, five exceptions, where an alloy of a different composition was given. The statement as to the percentage of iron was a very important one, for if manufacturers had to "guarantee that the iron in the alloy was less than 0·1 per cent.," then more would have to be paid for it. A serious cause of corrosion was stated to be foaming, but in regard to this the manufacturer was powerless, and it was a question entirely for engineers to deal with, by modifying designs and conditions of working. Attention was also called to avoiding starting the life of new tubes in foul water; manufacturers themselves had dealt with that point before. The notes dealt also with lead brass tubes; these had been used before and were worth further experiments and further use. Many other points covered revealed facts satisfactory to the manufacturer and threw responsibility on the engineer.

Dr. Carpenter also welcomed the issue of notes of this kind which gave in a compact form, in the present instance, the considered conclusions of Dr. Bengough and his colleagues on the committee. As proof of their usefulness, he stated that the notes in question had found a very rapid sale.

Engineer-Commander Allen asked Dr. Bengough whether he was satisfied as to the part played by laminations and spills in furthering corrosion. During the process of manufacture and pickling, acid may penetrate, salts may be formed which are squeezed in, forming "germs" which start corrosion. The oxidising treatment of the tubes mentioned by the author had much to recommend it; the Admiralty had fitted tubes so treated on some ships, but these as yet had not had enough steaming for a decision to be arrived at in the matter. In a collapsed section of a tube, there would be a greater tendency for an obstruction to occur and therefore a greater liability for corrosion to take place. He was glad the water flow had been considered. In the matter of water speed, this in the Navy could not be reduced to so low a figure as 2 ft. to 3 ft. per second, at which conditions would be relatively safe. In the Navy the water speed was higher than 6 ft. In the Navy, also, all the tubes some time or other were exposed to water containing oil. Leaky packing also was a nuisance, its effects were about the same as those of a perforated tube, but he was not quite clear as to why this should cause corrosion. The experience of the Navy in the matter of electrolytic protection was not very conclusive so far.

Dr. H. Moore said the author recommended an oxidising annealing at 350 deg. C., a treatment which had the effect of refining the crystalline structure. It was stated that "such treatment had but a trifling effect as regards softening the tube." In the section on "Mechanical Failure" reference was made to the failure of soft tubes by collapsing. A final treatment of 3 hours at 350 deg. C. ± 25 deg. was recommended for condenser tubes of 70 : 30 brass and 70 : 29 : 1 Admiralty tubes, and its inclusion in specifications was suggested. The work carried out by Mr. Beckinsale on the low-temperature annealing of Admiralty condenser tubes and reported in a paper to be taken later at the meeting, led to doubt whether the effect on the strength of the tube, of the treatment recommended by Dr. Bengough, was so trifling as he thought. Since the paper by him (the speaker) and Mr. Beckinsale, was printed they had made experiments on this point. Representative Admiralty condenser tubes of eight different makes, were heated for 3 hours at 350 deg. C. Particular care was taken in the control and measurement of the temperature, and there was no possibility of the deviation from 350 deg. C. having been as much as 5 deg. Pieces of Admiralty condenser tube brass, cold-rolled to different degrees of hardness, were submitted to the same treatment and tensile tests were made. The Brinell hardness of the tubes as supplied by the makers ranged from 135 to 165, and had been reduced by Dr. Bengough's treatment to from 78 to 92. The average Brinell hardness was 151 before and 85 after treatment. They had rarely found the Brinell hardness of condenser tubes as supplied and used to be lower than 120 and never so low as 85. In the tensile tests the two lots dealt with represented in their initial state the range of properties commonly found in condenser tubes. The effect of the treatment recommended by Dr. Bengough on the yield-point was worthy of note. In the softer material the yield-point had been reduced from 25 to 11, and in the harder material from 32 tons to 12 tons per square inch. These results made it quite clear that condenser tubes were softened very considerably by treatment at 350 deg. C. for 3 hours. The effect on microstructure was shown in slides exhibited. The structure before and after heating at 350 deg. C. for 3 hours, was shown for condenser tubes of initial Brinell hardness of 100, 140 and 165. Recrystallisation had occurred in the two more severely cold-worked specimens. Dr. Bengough had pointed out that the treatment he recommended caused recrystallisation in condenser tubes, and it was therefore not easy to understand his statement that the softening effect was trifling. As far as he (the speaker) was aware it was an invariable rule that the recrystallisation of severely cold-worked metals was accompanied by a marked degree of softening. Dr. Bengough might possess proof that tubes treated as he suggested were not too soft for their purpose. If this were so it was strange that makers commonly turned out their tubes in a very much harder state. He (the speaker) thought there would be no doubt that tubes softened to a Brinell hardness of 80 or 90 would be much more liable, not only to failure by collapse in service, but also to injury in handling. A thin walled brass tube softened to such a degree was easily indented.

Mr. R. T. Rolfe questioned the statement in the notes to the effect that the coppery spots in the tubes were not dependant on good or bad mixing of the copper and zinc in the crucible, and asked for further explanation on the point. He also asked for further data as to the ferrules, concerning which, Dr. Bengough said the 60 : 40 brass gave trouble, and referred also to 70 : 30 brass and the 70 : 29 : 1 alloy. More co-operation of the British Engineering Standards Association, the tube makers and the Research Committee was wanted on the point.

Dr. Rosenhain emphasized the very important part which stress upon the tube played in the matter of corrosion. Stress was one cause for corrosion, and pre-oxydising the tube might remove the stress as well as produce a protective oxydised covering. He did not think that Dr. Bengough could say that if a tube resisted a water pressure of 1,000 lb. per square inch, it was not going to undergo inter-crystalline corrosion. Stress might also lead to corrosion of the tubes at the inlet end; the gripping of the tube in the tube plate might have a considerable action.

Mr. W. B. Clarke mentioned some trouble he had with tubes through which hydrogen was passed; he then used a nickel-copper alloy which gave satisfaction, the porosity of the tubes having considerably decreased. Copper tubes immersed in aluminium also gave good results when used for the same purpose, although they only had a coating of aluminium.

In the course of his reply, Dr. Bengough, and with reference to Sir Gerard Muntz's remarks, said nearly all the tubes dealt with were in three or four classes, and the Admiralty alloy was recommended to be tried first. In regard to the alleged difficulty of keeping the iron impurity down to 0·1 per cent., the reply would be found in the paper by Messrs. Moore and Beckinsale, where the iron content was as low as that figure. In most of the tubes having had a long life, the iron was found to have been very low; the iron could be kept down in practice. Admiralty metal tubes were put first, one reason being that others were more expensive; further, many tubes were compared together and the conclusion arrived at was that the Admiralty metal tubes were the best. In regard to corrosion of collapsed tubes, the point was being further elucidated. The inlet corrosion could occur at the top or the bottom of the tube, the water flow in the tube having a spiral action; it played strongly against various parts of the tube where active corrosion took place. There was an inlet attack, a local corrosion. In regard to leaky packing, the linen packing retained the products of corrosion. A fairly hard tube was wanted in condensers for it to stand packing, and Dr. Bengough found that the Committee's recommendations left the tube sufficiently strong to stand the packing process. At the lower temperature Dr. Moore advocated, the tubes would not be regularly annealed. The ferrules of 60 : 40 alloy gave trouble and had been very generally abandoned; great improvement had been found in making them of Admiralty brass. In regard to stress, Dr. Bengough said he would consider Dr. Rosenhain's suggestions. He had no experience in the matter of nickel preventing porosity to hydrogen, but it was worth trying. Dr. Bengough added that he would reply fully to the discussions by a written communication to the proceedings.

Annual Dinner.

The Annual Dinner of the Institute, at the Trocadero Restaurant, was largely attended and presided over by Mr. Leonard Sumner, M.Sc., who gave the loyal toast. Professor Carpenter proposed "The Kindred Societies," associating with it the name of Mr. W. B. Worthington, President of the Institution of Civil Engineers, and Dr. Hele-Shaw, President of the Institution of Mechanical Engineers. Sir Joseph Petavel, F.R.S., proposing "The Institute of Metals," referred to the early days when the Institute was founded, and traced its progress. The President replied, and the only other toast was that of "The Guests," proposed by Sir John Dewrance and replied to by the Rt. Hon. F. G. Kellaway, M.P., and Lieut.-General Sir Travers Clarke, K.C.B.

(To be continued.)

Board of Trade Surveys.—The Board of Trade has issued a list of fees and expenses payable in connection with surveys and other mercantile marine services. This supersedes the list dated 1920, and can be obtained at the price of 3*d.* from H.M. Stationery Offices.

Ateliers de Constructions Electriques, Charleroi.—This Belgian electrical engineering company, whose London address is 56, Victoria-street, S.W. 1, has resumed the publication of its bulletin in French. The issue No. 93, for January, shows various parts of their works as they stood before the war, as they were during the German occupation and as they have since been reconditioned by the company.

INDUSTRIAL NOTES.

THE difficulties which have arisen in the shipbuilding and engineering industries throughout the country remain unsettled. With reference to the shipbuilding difficulty, representatives of the men have called on the Minister of Labour and asked him, in conformity with the provisions of the Industrial Courts Act, 1919, to take steps to promote a settlement. They had asked the employers to join them in their application to the Minister of Labour, but the employers declined since, in their opinion, no useful purpose could be served by an official inquiry into the position of the shipbuilding industry. They adhere to their statement to the effect that the only way to arrive at an improvement of the industry is to withdraw the 26*s.* 6*d.* weekly war bonus. Orders are absolutely lacking, and no Court of Inquiry would bring any. Speaking a few days ago to a gathering of railwaymen in Birkenhead, Mr. J. H. Thomas referred to the shipbuilding crisis and said that if Government let the matter drift, *i.e.*, did not appoint a Court of Inquiry, terrible consequences must follow. Mr. Thomas appears to view the railway situation in a somewhat different light, for at the same meeting he is reported to have stated: "You know we have received an application that the Scottish railways' award shall apply to England and Wales. Some branches are passing resolutions that we must not budge. That is not the spirit in which to approach the question. High rates and fares vitally affect railwaymen as well as the community. Whilst determined to maintain fair conditions, we must not be unmindful of our public obligations."

The shipbuilding unions, on the suggestion of Dr. Macnamara, the Minister of Labour, discussed the situation last Monday with the employers; it was reported that neither side was in a position to make proposals on the question at issue. Further meetings of the union representatives separately and with the employers have been arranged for.

In regard to the crisis which has arisen in the engineering industries, Mr. J. T. Brownlie, the president of the Amalgamated Engineering Union, speaking at Rugby, said the employers were placing the whole onus of finding a way out of the difficulty upon the union. It would appear, however, that the executive of the union should be capable of dealing with the problem; the executive, it will be remembered, recommended the men to vote in favour of the employers' proposals on the questions at issue, namely, freedom of management and overtime. The executive surely cannot be afraid of a serious rebuff from the men on approaching them again in the matter, considering that only about one-fifth of the members, as stated on page 137 *ante*, took the trouble to record their vote. But, as in the case for the shipbuilding operatives, Government is appealed to for intervention. Mr. Brownlie stated at Rugby: "If ever there was a time in the history of the nation when the leader of the Government should ask the parties to meet him to discuss the question with a view to bridging over the difficulty, that time is here and now." Mr. Brownlie added that his colleagues on the executive were prepared to sit down with the employers to try and find a way out of the difficulty satisfactory to both parties. One must hope for the best as to the outcome of such a meeting if it takes place, but since the counsels of the executive have been ignored by the men in the early stages of the difficulty, there is always a doubt as to whether they would be heeded in the later stages; the one ray of hope is afforded by the fact that only a very limited number of men took the trouble to vote, and a second ballot, if there should be one, might entirely reverse the first.

Matters were carried no further at a meeting of representatives of the federation and union on Wednesday. At this meeting the union advanced proposals which were unacceptable to the federation. These proposals, when explained by the union, conveyed to the employers, according to an official statement issued, the impression that the union was determined to retain restrictions imposed during the abnormal conditions of war, and that they were diametrically opposed to what had been previously agreed to by the union executive. The Amalgamated Engineering Union is now in touch with the Federation of Engineering and Shipbuilding Trades, and it is possible complications will ensue in that direction. The notices in the engineering trades expire on Saturday.

A strike of tug-boat men on the Mersey, against reduction in wages, has collapsed, and the men have accepted the condition amicably arrived at in negotiation between the men's representatives and the employers.

THE BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION.

A MEETING in support of the objects of the British Non-Ferrous Metals Research Association was held at Birmingham on Friday, the 3rd inst. The chairman of the Association, Mr. Thomas Bolton, presided, and said that the Association appealed in the first instance to those actually engaged in the industry as manufacturers; he thought, however, that its objects could appeal with equal strength to users. It would, therefore, be to the advantage of everybody connected with the non-ferrous metals to become a member of the Association. From the very earliest days all improvements in handicraft came from men applying their brains to improve the value of the work of their hands. That was really the foundation of what they meant by research. The importance of research to industry had been fully recognised by the Government, as had also the advantage of research associations, in order that work might be effectively and economically carried out. It had also been recognised that the associations were very difficult to start, and for that reason a fund had been placed at the disposal of the Department of Scientific and Industrial Research, out of which financial assistance was given to the associations. Referring to a suggestion that the Association should found a certain number of temporary fellowships for post-graduates at the universities to enable men to remain at college for another year for the purpose of devoting themselves to research work, he said that suggestion had been acted upon to a small extent, and he thought it deserved a great deal more consideration. He believed it would be welcomed by the universities, and it seemed to serve a double purpose by enabling some of the minor researches to be carried on at small expense, and attaching more closely to the industry brilliant young men who might otherwise drift off in another direction. After indicating the various branches of research undertaken by the Association, Mr. Bolton added that the programme of work they had in hand was estimated to cost considerably more than their anticipated income, and for that reason they must vigorously endeavour to get more money.

Vice-Admiral Sir George Goodwin emphasised the claims which the Association had to the consideration of those commercially interested in the use of non-ferrous metals. For certain purposes marine engineers liked iron and steel, because it was cheaper and stronger, but those metals did not possess many qualities that the non-ferrous metals did. Development had not taken place in non-ferrous metals as quickly as they would like, and progress in engineering had been retarded thereby. Because of that delay, steel makers had put themselves to the task, and were progressing very rapidly, more rapidly than some of the non-ferrous manufacturers. For those particular parts to which he was referring they would prefer to use non-ferrous metals, and he thought there was a very wide field for the Association in that connection.

Dr. Rosenhain expressed the opinion that the establishment of post-graduate fellowships was one of the most important things they could do, because they must attract, if they wanted to be successful, the brilliant young men from the universities to the subject. There was no better way of doing that than by stimulating and encouraging financially post-graduate work. In the past, lack of development of the results of researches had been more felt than the lack of research itself. Research associations such as theirs would help to bring about immediate utilisation of results. They were faced with serious competition from the fact that incorrodible iron alloys were becoming increasingly available. A non-ferrous alloy equally incorrodible was yet to be discovered, and that was a problem which was by no means insoluble. If it was solved it would help the non-ferrous industry considerably in that very serious rivalry.

Sir Henry Fowler emphasised the importance of research to users of non-ferrous metals, and trusted that the railway companies would soon be in a position to support such work. Users could help the Association as members by testing materials under service conditions.

Sir Gerard Muntz paid a tribute to the work of the Chairman of the Association, and emphasised the fact that research should preferably be handed over to specialists. In the factory it was frequently neglected for other pressing work.

Sir Frank Heath, Secretary of the Scientific and Industrial Research Department, congratulated the Association on the extraordinary way in which its membership and activities had expanded during the previous year. He gave several illustrations to show the value of co-operation between user and producer. He thought the provision of an intelligence service was one of the most valuable things an association could do; he was also particularly interested in the projected establishment of research studentships, and offered the assistance of his Department in working out a scheme. The growing appreciation of the value of research was indicated by the absence of any reference to his Department in the proposals made by the Geddes Committee.

THE PRODUCTION OF ACCURATE SCREW THREADS.

TO THE EDITOR OF ENGINEERING.

SIR,—I wish to call attention to the position of the question of the gauging and degree of accuracy attained in the production of screw threads in the engineering industry of this country, and perhaps more particularly in the automobile industry, which branch of engineering uses such large quantities of comparatively small bolts, studs and nuts that must be tight fitting to satisfactorily withstand the tendency to unscrew on account of vibration.

During the war much good work, both of a development and an educational character, was done by the National Physical Laboratory and the British Engineering Standards Association, more particularly in connection with inspection methods, and it is hoped that in time industry will absorb and take full advantage of this work.

It is still not uncommon to see an attempt made to gauge, for example, bolts by means of complete form "go" and "not go" ring gauges. It does not seem to be realised that a screw thread comprises at least five independent elements, and that inaccuracy in any one, some of which are comparatively unimportant as affecting the fit, will entirely upset this procedure, and that in consequence a hopelessly undersize bolt may still refuse to enter the "not go" gauge, because of an unimportant inaccuracy in the opposite direction in perhaps one dimension.

Furthermore, one sees a screw thread measured over the top diameter by a micrometer. The information thus obtained is quite valueless as regards the probable fit of a nut. It may be assumed that the thread is true profile, but even this justification will not hold good if the later B.E.S.A. reports are being followed, as the tolerance therein permitted on top diameter is much greater than on effective diameter, as of course should logically be the case.

The tables issued by the B.E.S.A. giving the relationship between pitch error and effective diameter over various lengths of engagement are a long step in the right direction, but to make them useful it requires simple and quick means of measuring, first the simple effective diameter over one thread, and, second the compound effective diameter over the length of engagement, to be available.

The three roller method is, of course, well known, but it is very slow, and unless the flank angle is correct, or alternatively the angle error is known and the roller diameter is selected so as to measure half-way down the flanks, at what is known in America as the pitch diameter, the resultant figure for effective diameter is not the true simple effective diameter, and so further unknown erroneous factors are introduced.

It is not generally appreciated that a nut that is a nice spanner fit on a bolt does not usually or necessarily attain that condition by extreme accuracy of its various elemental dimensions, but more frequently by a combination of inaccuracies that necessitate and permit plastic flow on the thread faces to take place as the nut is screwed on. If no such action takes place the nut is in all probability not spanner tight. It is, of course important that the amount of plastic flow necessitated in order to pass the nut shall not be so great as to cause permanent damage to the threads to such a degree as to affect their strength.

In hard metals, such as cast-iron and to a less degree aluminium, this is a most important matter, as little plastic flow is possible and in consequence very high stresses may be induced in screwing in a stud, and threads of a degree of inaccuracy that are quite satisfactory for steel are useless, and in extreme cases may even cause complete stripping of the thread. The practice of adopting a greater length of engagement for studs in aluminium is based on the lower shear strength of aluminium, but unless pitch inaccuracy is kept within sufficiently close limits so that the act of screwing in does not unduly strain the threads, the supposed advantage may be completely neutralised by the greater length of engagement.

The elemental dimension that most readily causes slackness or tightness is, of course, the pitch, and any pitch error causes a tighter fit over the length of engagement. It is, therefore, important to know the pitch error and the effective diameter before one can judge the suitability of a screw thread for a given purpose, and a simple and quick means of measuring these values would greatly enhance the usefulness of the work accomplished by the B.E.S.A., and be of inestimable benefit to the engineering industry generally when fully appreciated and in general use.

It is, of course, useless taking steps to control the accuracy of bolts and studs within suitable limits, unless at the same time similar steps are taken in regard to nuts and threaded holes. It does not appear possible to satisfactorily measure the threaded hole, but inspection of taps should meet the case, and a rapid means of checking that the important elemental dimensions of taps were within predetermined limits would, if generally adopted, go far to fill the want.

It is of course clear that the tap which forms the basis of the die from which the bolt thread is produced as well as the tapped hole is the member that should be seriously attacked in the first place.

Yours faithfully,

A. A. REMINGTON.

Lloyd's Bank Chambers, New-street,
Birmingham, March 6, 1922.

THE INTERNAL MECHANISM OF COLD-WORK AND RECRYSTALLISATION IN CUPRO-NICKEL.*†

By FRANK ADCOCK, M.B.E., B.Sc., Member (Teddington).

AN inquiry into previous investigations on the process of cold-work and recrystallisation in metals led to the belief that progress could be made only if good photo-micrographs were obtainable from specimens of metal which had been severely cold-worked.

Search was accordingly made for a suitable metal together with the necessary etching reagents, in the hope that better microsections would result, and that the study of these microsections in the various stages of cold-work and subsequent annealing would yield some information regarding the changes which took place within the metal during these operations.

Choice of Metal.—Commercial cupro-nickel (copper 80 per cent., nickel 20 per cent.) was finally selected as the material for the experiments, as it was known that the metal could be polished and etched without much difficulty, and that the required annealing temperatures would be well within the range attainable with a nichrome wire-wound electric furnace. Microsections of the cast metal revealed the presence of strongly marked "cores" or "dendrites" which were very persistent under heat-treatment, and it was not until the material had been annealed in a muffle furnace at 1,000 deg. C. for 24 hours that the etching reagents failed to show unequal distribution of the copper and nickel content. As would be expected, the metal showed a coarse structure after such a drastic annealing, many of the crystal grains being several millimetres in diameter, and were occasionally twinned: probably as the result of cropping the ingot previous to annealing. It was with some reluctance that a homogeneous solid solution alloy was adopted in lieu of a pure metal, but it was realised that a pure metal which would successfully withstand the punishment of the rolling mill would probably give rise to serious difficulties during the polishing of the specimens for microscopic examination.

Method of Etching.—The copper-nickel alloy proving otherwise adaptable for the investigation, the usual methods of etching were tried during the preliminary experiments, but only with partial success. Both chromic acid and ammonia persulphate gave fair results, and an electrolytic attack in a solution of dilute sulphuric acid brought out the crystal grain boundaries while the polished surfaces of the grains themselves remained practically unaffected. Electrolytic etching in a solution of citric acid (100 grammes per litre) gave the best results with cupro-nickel, and to most of the work a metal filament electric lamp in series with the etching cell and the 100-volt supply, passed about the correct current (one-tenth of an ampere) for microsections of ordinary dimensions. The current density could be varied within fairly wide limits without seriously affecting the quality of the etching, but a reduced current was necessary when etching the polished edges of thin specimens, since the borders were often deeply etched before the central part of the specimen showed signs of attack. A platinum cathode was used while the specimen to be etched was made the anode of the electrolytic cell and was supported by means of a platinum wire. As has been previously pointed out by the author,‡ the addition of a trace of nitric acid to the citric acid electrolyte (one drop of concentrated acid per 20 c.c. of electrolyte) tended to remove the patchy appearance which was sometimes produced when the sample was etched in the pure citric acid solution. Reference must also be made to an electrolyte made by dissolving molybdic acid in ammonia solution. This electrolyte gave results similar to those produced by the citric acid solution, but possessed the disadvantage that constant additions of ammonia were required to compensate for losses on standing.

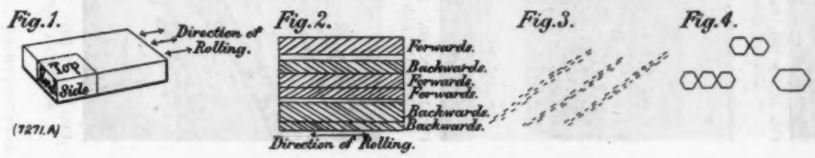
Cold-Working of the Metal.—An annealed ingot crop was passed repeatedly through the rolls until the thickness was reduced from 1 in. to ⅛ in., portions of the metal being removed from the mass when the thicknesses of ½ in. and ¼ in. were attained. This process yielded samples of the metal which had been reduced approximately 50 per cent., 75 per cent., and 88 per cent. respectively without intermediate annealing. It was not thought that the reduction of 88 per cent. approached the limit of which the material was capable, since another ingot crop was successfully reduced in thickness from 1·25 in. to 0·04 in., a reduction of nearly 97 per cent.

In this connection it should be mentioned that this particular ingot crop was in the "as cast" state, and had not been annealed at 1,000 deg. C. for the removal of the "cores," as was the case with the metal used for the investigation. The rolled material after having been reduced to the desired thickness was sawn into small pieces suitable for microsections, care being taken to note the relationship of the faces of the sample to the direction of rolling. For convenience these faces will be referred to as the "top," "side," and "end" sections respectively, and their relative positions with regard to the direction of rolling will be seen in Fig. 1.

Micro-Examination of the Cold-Worked Material.—Preliminary tests indicated that the 75 per cent. reduced material showed characteristics intermediate between those exhibited by the 50 per cent. and the 88 per cent. reduced material, and in consequence only the 50 per cent. and the 88 per cent. reduced metal was investigated further.

Eighty-Eight per Cent Reduced Material.—When etched with the citric acid electrolyte the "side" sections showed up the crystal grains clearly as long strips, and while some of them were almost devoid of surface markings, others were covered with dark sloping lines. These lines possessed appreciable width and were generally slightly curved and, under low powers (100), often appeared branched, but an examination under higher powers suggested two or more sets of lines were present, making angles of from 25 deg. to 40 deg. with the direction of rolling. (Fig. 10 overleaf). Lines inclined forwards and backwards in respect to the direction of rolling were observed in different crystal grains of the same specimen, but both sets of lines were not seen within the borders of a single grain. Fig. 2 will perhaps help to make the meaning clear. As far as could be ascertained, the general appearance of the crystal grains remained the same for the whole of their length, and the fact that a number of clear grains were observed to be "sandwiched" between other grains deeply marked suggested that the appearance or non-appearance of the markings and their direction (forwards or backwards) depended primarily on the original orientation of the crystal grains. Contrary to expectation, the grain boundaries could always be seen distinctly in spite of the great distortion the metal had undergone, but little could be made of the dark lines even under the highest powers available (1,000), except that they were possibly built up of a number of short, roughly parallel dark lines staggered in respect to one another (Fig. 3).

Occasionally the crystal grains in which the sloping lines were absent showed faint wavy striæ more or less parallel to the longer edges of the crystal grains, and incidentally to the direction of rolling.



Under low powers the "end" sections of the 88 per cent. reduced material appeared rather confused, but the finer detail was well brought out under moderate magnification (Fig. 11 on the next page). From this point of view the deformed crystal grains appeared as very irregular ellipses, with numerous surface markings roughly parallel to their major axes.

Examination of the "top" section revealed that the crystal-grains had been considerably elongated but had not been diminished in thickness to the great extent apparent in the "side" sections. As with other sections, the surfaces of the crystal grains (after etching) were strongly marked with a number of dark lines, but in this case the lines were orientated in a direction at right angles to the direction of rolling (Fig. 12).

Examination of the 50 per Cent. Reduced Material.—It was anticipated that further light would be shed on the nature of the dark lines, &c., by investigating a material which had undergone less cold-working and which consequently presented a less confused structure. Fig. 13 is a photomicrograph of the "side" section of the cupro-nickel which had been reduced 50 per cent., and it is noteworthy that the crystal grains were sharply defined and retained different orientations (shown by surface etching), in spite of the fact that the metal had been reduced to half its original thickness.

Fig. 14 gives a clue to the nature of the distortion suffered by a twinned crystal during the rolling process, for the narrow twin is "stepped" at places where the dark lines or etch-bands of the large surrounding grain come in contact with its boundaries. Under favourable conditions the ordinary grain boundaries may be seen to be "stepped" where the dark lines meet them, as is shown in Fig. 15.

Note.—This particular specimen had been annealed for half an hour at 435 deg. C. to 440 deg. C., but the "stepped" appearance of the crystal boundaries had been observed in non-annealed samples. Examination of the "top" and "end" sections as well as the "side" sections of the 50 per cent. reduced material indicated that, broadly speaking, the orientation of the crystal structure, as indicated by etch-pits, remained approximately constant over most of the surface of a deformed crystal grain, but that in certain regions usually near the grain boundaries the distortion had apparently been more severe and the etch pits were less distinct.

Bending of the Crystal Structure.—The possibility of the "bending" of the crystal structure being too important to ignore when dealing with the mechanism of cold-work in metals, a number of observations were made in areas where the crystal orientation appeared doubtful. Deep etching and high magnification necessarily rendered photography difficult, but Figs. 16 and 17 convey the impression that the crystal structure has suffered change in orientation, either gradually or in a series of minute steps.

Cavities in the Deformed Metal.—Similar cavities in the metal to those visible in Fig. 16 may be seen in Figs. 13, 14 and 15, but as the result of lower magnification they appear as short dark lines following the direction of rolling. A few of these lines were visible in the unetched sections, and the remainder made their appearance very rapidly on etching, a fact which suggested that either the cavities existed before etching and were somewhat smeared over during polishing, or that some inclusion very soluble in the etching reagent existed in the metal. Under higher powers the cavities were also apparent in the "end" sections of the metal, and from this aspect they often presented themselves as curious double or treble hexagons (Fig. 4).

Possibly the cavities were actual ruptures caused by intense local stresses during rolling, since Fig. 16 shows cavities located in a region where the actual crystal structure has been apparently deformed or bent.

Annealing of the Cold-Worked Material.—In order to investigate the changes which took place in the cold-worked material on annealing, specimens were heated for periods of half an hour in an electric tube furnace and were then subjected to micro-examination. After a few preliminary trials were made—for the purpose of ascertaining suitable ranges for the annealing temperatures—a number of samples of the metal which had been reduced 50 per cent. and also 88 per cent. by rolling were annealed at progressively higher temperatures, and it was hoped that the micro-examination of these series would yield some information concerning recrystallisation and other changes which took place in the worked metal. Most of the annealing was carried out in an "air" atmosphere as a vacuum was not obtainable at the time; and while the temperature of the electric furnace was maintained as constant as possible for any one annealing, slight variations were sometimes unavoidable.

Examination of the 88 per Cent. Reduced Series.—The table below shows the annealing temperatures for this series, together with the diameter of the impression made in the respective samples by a "Baby" Brinell machine loaded to 100 kg. and fitted with a ball 5 mm. in diameter.

TABLE I.

Sample.	Annealing in Degrees C. Range.	Temperature Centigrade. Average.	Diameter of Impression in Mm.
T13..	Unannealed	—	0·68
T3	412–416	414	0·70
T6	440	440	—
T15..	460–480	470	0·71
T11..	490–495	492	0·75
T10..	495–500	497	0·81
T16..	505–510	507	0·83
T5	520–540	530	0·94
T8	550–570	560	0·98
T14..	630–640	635	1·05
T	660	660	1·05
T17..	810	810	1·11
T12..	960–980	970	1·19

The original ingot crop after the drastic annealing prior to cold-rolling gave a rather irregular impression under the Brinell machine—about 1·2 mm. in diameter.

This series of samples (88 per cent.) reduced will now be dealt with under the headings of the respective annealing temperatures.

T3 *Annealed* 412 *Deg. to* 416 *Deg. C.*—Although no new crystal grains were discoverable in the sample, yet it was evident that changes had been taking place in the metal, for the dark lines or etchbands generally visible in the unannealed metal now showed up more distinctly. Further, certain crystal grains in which the sloping lines were absent now showed marked striations in the direction of their length ("side" section) in the place of the faint markings discernible before annealing (Fig. 18).

T6 *Annealed* 440 *Deg. C.*—Minute new crystals were observed in this specimen, but owing to the very high magnification necessary it was impossible to obtain a satisfactory photograph showing their presence. It was apparent, however, even at this early stage, that the new grains were being born along the previously-mentioned lines or etch bands, but under the lower powers the general aspect of the specimen differed little from that of the preceding sample.

T15 *Annealed* 460 *Deg. to* 480 *Deg. C.*—At this stage the newly arrived grains had attained such dimensions as to be visible under quite low powers (Fig. 19), but it will be observed that although in some of the original crystal grains the process of recrystallisation was quite advanced other old grains still remained in which no new grains could be seen.

Fig. 20, which represents a "side" section under higher magnification (650), indicates how the new grains had formed on the sites of the etch-bands, and the straight boundaries visible within some of the new grains suggest that twinned crystals were not unknown at this period of recrystallisation.

Fig. 21 gives a general view of the "end" section, but the section was too deeply etched and the magnification too small to demonstrate the new grains properly.

T11 *Annealed* 490 *Deg. to* 495 *Deg. C.*—The average size of the new grains seems to have increased slightly, and as will be seen from Fig. 22, page 307, some of the old grains showed marked striations in the direction of their length ("side" section). That connection existed between these striations and the development of some of the new grains will be observed in Fig. 23, where several of the new grains are seen growing on the dark lines which pass through the old crystal grain in the direction of rolling.

T10 *Annealed* 490 *Deg. to* 500 *Deg. C.*—Little change is apparent from the preceding specimen. Fig. 24 (350) shows clearly the tendency of the new grains to form along the sloping lines visible within some of the old grains ("side" section).

At this stage the "top" sections showed the new

* Paper read before the Institute of Metals, on Wednesday, March 8.

† Figs. 5 to 9 will be given in the succeeding article.

‡ *Journal of the Institute of Metals*, No. 2, 1921, vol. xxvi, page 362.

INTERNAL MECHANISM OF COLD-WORK AND RECRYSTALLISATION IN CUPRO-NICKEL.

(*For Description, see Page* 305.)

ETCHED WITH CITRIC ACID.

FIG. 10. × 100. Reduced 88%. Side section. Rolled ←→

FIG. 11. × 350. Reduced 88%. End section. Rolled ⊙

FIG. 16. × 650. Reduced 50%. Unannealed. Gradual change in orientation.

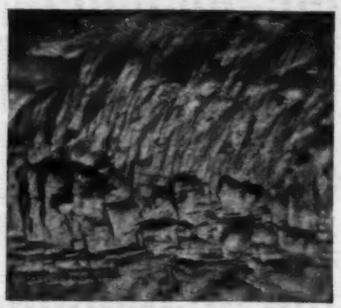


FIG. 17. × 650. Reduced 50%. Unannealed. Gradual change in orientation.

FIG. 12. × 100. Reduced 88%. Top section. Rolled ←→

FIG. 13. × 100. Reduced 50%. Side section. Rolled ←→

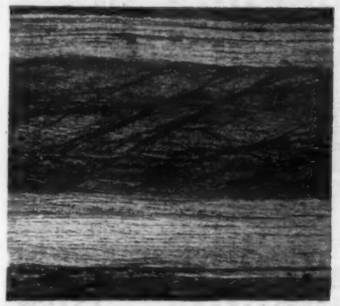


FIG. 18. × 100. Reduced 88%. Annealed 412-416° C. Side section. Rolled ←→

FIG. 19. × 100. Reduced 88%. Annealed 460-480° C. Side section. Rolled ←→

FIG. 14. × 100. Reduced 50%. Side section. Rolled ←→

FIG. 15. × 100. Reduced 50%. Annealed 435-440° C. Rolled ←→

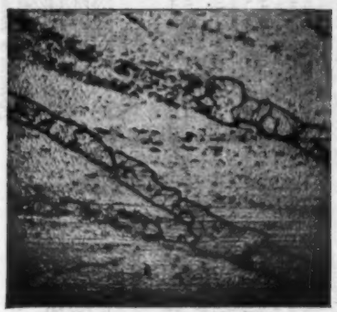


FIG. 20. × 650. Reduced 88%. Annealed 460-480° C. Side section. Rolled ←→

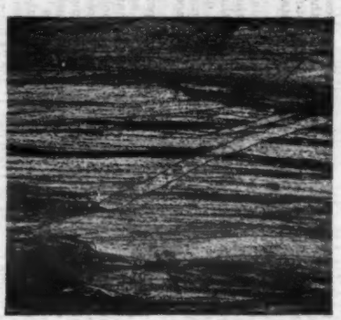


FIG. 21. × 100. Reduced 88%. Annealed 460-480° C. End section. Rolled ⊙

[SLIGHTLY REDUCED IN REPRODUCTION.]

INTERNAL MECHANISM OF COLD-WORK AND RECRYSTALLISATION IN CUPRO-NICKEL.

(*For Description, see Page* 305.)

ETCHED WITH CITRIC ACID.

FIG. 22. × 100. Reduced 88%. Annealed 490-495° C. Side section. Rolled ←→

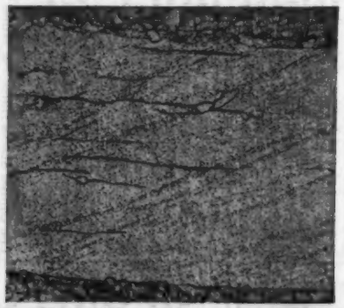


FIG. 23. × 350. Reduced 88%. Annealed 490-495° C. Side section. Rolled ←→

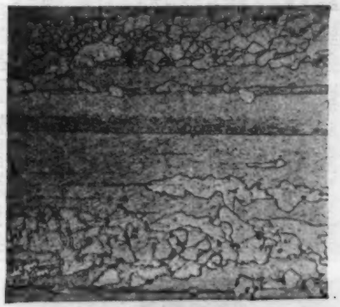


FIG. 28. × 350. Reduced 88%. Annealed 520° C. Side section. Rolled ←→

FIG. 29. × 350. Reduced 88%. Annealed 550-570° C. Side section. Rolled ←→

FIG. 24. × 350. Reduced 88%. Annealed 490-500° C. Side section. Rolled ←→

FIG. 25. × 100. Reduced 88%. Annealed 490-500° C. Top section. Rolled ←→

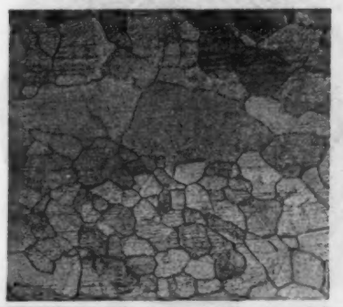


FIG. 30. × 350. Reduced 88%. Annealed 630-640° C. Side section. Rolled ←→

FIG. 31. × 100. Reduced 88%. Annealed 630-640° C. End section. Rolled ⊙

FIG. 26. × 350. Reduced 88%. Annealed 490-500° C. Top section. Rolled ←→

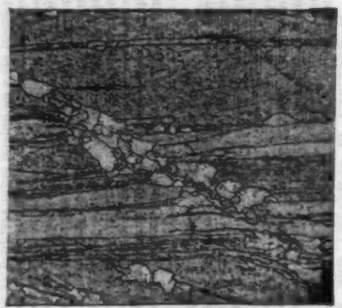


FIG. 27. × 350. Reduced 88%. Annealed 490-500° C. Side section. Rolled ←→

FIG. 32. × 100. Reduced 88%. Annealed 960-980° C. Side section. Rolled ←→

FIG. 33. × 350. Reduced 50%. Annealed 435-440° C. Side section. Rolled ←→

[SLIGHTLY REDUCED IN REPRODUCTION.]

grains appearing on the sites of the etch-bands running at right angles to the direction of rolling, and it is interesting to compare Figs. 25 and 26 depicting the partially annealed metal ("top" section) with Fig. 12, which illustrates the same aspect of the unannealed material.

T10 *Annealed* 495 *Deg. to* 500 *Deg. C.*—At this stage some of the old grains had become almost covered with the new grains, while others still existed which showed well pronounced striations in the direction of their length ("side" section) and only isolated groups of new grains.

Fig. 27 represents a portion of an old grain where recrystallisation was belated and in which a group of new grains has evidently formed on the site of a sloping etch-band ("side" section), but some of the new grains have shown a marked inclination to expand along the striations which are parallel to the direction of rolling.

T16 *Annealed* 505 *Deg. to* 510 *Deg. C.*—Appearance is practically identical with the preceding specimen.

T5 *Annealed* 520 *Deg. to* 540 *Deg. C.*—Some areas of the specimen were entirely covered with new grains, but a few old grains remained where the process of recrystallisation was apparently retarded and where the new grains were seen to have formed on the striations running in a direction parallel to the rolling. Fig. 28 ("side" section).

T8 *Annealed* 550 *Deg. to* 570 *Deg. C.*—Fig. 29 shows one of the few areas of the sample where recrystallisation was not complete, and it was noticeable that the new grains which had formed in the area, where unrecrystallised material still existed, were of larger average size than those depicted in the zone below. Further, the lately arrived grains were not equi-axed and were often longer in the direction of rolling than in any other, and their boundaries in some instances appeared incomplete. Changes had apparently taken place in the unrecrystallised material, for the etching reagent showed the presence therein of rather vague boundaries and differences in the surface attack suggestive of twinning. One of these boundaries is visible in Fig. 29.

T14 *Annealed* 630 *Deg. to* 640 *Deg. C.*—Recrystallisation was probably complete, as is indicated in Fig. 30 (350), which shows a typical field.

Fig. 31 represents the "end" section of the same material at lower magnification, and illustrates the great variation in the crystal grain size existing in different areas of the sample annealed at this temperature.

T *Annealed* 660 *Deg. C.*—This sample resembled the preceding closely, and great variation in the grain size in different regions was especially noticeable.

T17 *Annealed* 810 *Deg. C.*—Not examined microscopically.

T12 *Annealed* 960 *Deg. to* 980 *Deg. C.*—As will be seen from Fig. 32 the new crystal grains had become comparable in size with those existing in the metal before rolling, and as might be expected in a worked and annealed metal were frequently twinned.

(*To be continued.*)

NORWEGIAN SHIP CONTRACTS IN ENGLAND.—In a statement before the Norwegian Parliament reference was made to the large number of Norwegian contracts for new tonnage in England which it had been found expedient to cancel. Out of about 1,000,000 tons deadweight originally contracted for, there are now only about 150,000 tons deadweight left, divided among some 18 boats. At the same time some orders have quite recently been placed in Germany. Thus one owner has contracted with the Deutsche Werke three motor vessels, one of 8,800 tons and two of 8,000 tons each.

TELEPHONES IN MINES CONTAINING GAS.—That the ordinary, apparently innocent telephones used in the underground depths of coal mines are capable of igniting gas and thus bringing about disastrous mine explosions is the novel finding of an investigation just conducted by the United States Bureau of Mines at its experiment station at Pittsburgh, Pa. The danger of gas ignition and explosion does not reside in the employment of such current as is necessary for talking over telephones, but results from the ringing of the magneto. Actual tests on an ordinary mine telephone were made in a large testing gallery of approximately 400 cub. ft. capacity, used by the Bureau of Mines for investigation of all types of electrical equipment in gaseous atmospheres. The gallery is so arranged that it can be filled with an explosive mixture of natural gas and air, the gas being taken from city mains. The inner and outer doors of the telephones were left open so that the gas could easily enter the interior of the instrument. Another telephone was placed at a point some distance from the gallery and connected to the first telephone through a metallic circuit. The telephone inside the gallery was fitted with an attachment that permitted the ringer to be operated from outside the gallery. By another attachment, the receiver circuit could be opened or closed in like manner. The outside telephone could be operated in the usual way. Tests were made by ringing the telephone inside the gallery when filled with gas, but not connected to the external circuit; by ringing the inside telephone when connected to the external circuit, and by ringing the outside telephone while the receiver circuit of the inside telephone was being opened and closed. As the results of several series of trials made under varying conditions, numerous ignitions and explosions of the gas in the gallery were obtained. The results of the investigation indicate that the ordinary type of mine telephone, while designed to have a certain measure of dust and moisture tightness, is not an explosion-proof device, and is, therefore, not safe in gaseous atmospheres. The Bureau of Mines indicates the need of the establishment of safety standards for mine telephones that may be required to operate in gaseous atmospheres.

SOME CASES OF FAILURE IN "ALUMINIUM" ALLOYS*.

By W. ROSENHAIN, D.Sc., F.Inst.P., F.R.S. (Vice-President). (From the National Physical Laboratory.)

THE importance of alloys of aluminium as materials of engineering has increased in recent years, and so much time and attention has been devoted to researches on these materials, that records of practical experience obtained with them are of special interest. In this connection a good deal is heard at times of cases of failure arising from growth or distortion in what are described as aluminium alloy castings, particularly so-called die-castings. Several cases of failure of this kind having been brought to the notice of the author, he thinks it worth while to place the details on record, in order to counteract as far as possible the damaging effects of such statements upon the reputation of perfectly satisfactory and reliable materials.

Of the number of cases which have come under examination, two typical ones have been selected for description here. The first of these was a thin-walled casting forming the outer casing of an electricity meter which had been in use under one of the municipalities of the London area. These meter cases had distorted

FIG. 1.

FIG. 2.

and cracked in the course of one or two years, and had all to be replaced. The case sent for examination was very badly buckled and cracked, and the material could readily be broken up with the fingers.

Casual examination at once showed that the material could hardly be described as an aluminium alloy in the ordinary sense in which that term is used as covering light alloys consisting mainly of aluminium. A chemical analysis was accordingly made, with the following results:

	Per Cent.
Aluminium	17·1
Zinc	81·21
Copper	0·40
Tin	0·68
Iron	trace
Magnesium	trace

It will be seen at once that the above figures prove the material to be not a light alloy of aluminium but an alloy consisting mainly of zinc, containing some aluminium and a small amount of copper. A good deal of work has already been done on these alloys, and their tendency to undergo spontaneous changes and disintegration has been studied and described in a paper contributed to this Institute by the present author with Dr. Haughton and Miss Bingham.† In view of the results described in that paper, it is not surprising to find that castings of the composition indicated above are not stable or satisfactory when used in a thin form in which small changes of dimension are likely to set up severe stresses.

The second case to be described relates to a much simpler form of casting. This is a cast name-plate used on a particular type of air compressor. One of these name-plates, originally described as an aluminium casting, after being attached to the machine in question for a number of years, during service in India, was returned to the makers of the machine in the condition illustrated in the illustrations, Figs. 1 and 2. Fig. 1 shows a front view of the plate, on which the four screw holes by which it had been firmly attached to the iron casting of the machine are clearly seen. On this illustration the growth and distortion of the plate are indicated by the peculiar distortion of the lettering. The true extent of this distortion, however, only becomes evident in a side view of the plate, as shown in Fig. 2. This plate was submitted to the author for examination by Messrs. Reavell and Co., Limited, of Ipswich, who have very courteously given him permission to publish the details in full.

Preliminary examination indicated that this plate also was not truly a light alloy casting, since its weight was obviously too great. Chemical analysis was therefore carried out with the following results:—

	Per Cent.
Aluminium	43·12
Zinc	54·00
Copper	1·57
Iron	0·62
Tin	0·52
Silicon	0·17

The above composition shows that here again is an alloy consisting mainly of zinc, although the proportion of aluminium is distinctly larger than in the previous example. Copper is again present. This particular alloy does not fall within the range carefully studied in the paper (by the author, Haughton, and Bingham) already referred to. At the same time it is likely to contain at all events a certain amount of the unstable phases described in that paper, and the failure and disintegration of this name-plate are probably an example of the same kind of action as that studied in that paper. Again, however, the alloy cannot fairly be described as an aluminium alloy in the usual sense.

The two examples cited and described in detail above are typical of others which have come under the author's notice. They serve to show that the materials which undergo serious growth, distortion and disintegration in the course of service, are not, properly speaking, aluminium alloys in the ordinary sense of that term, and that the frequent reference to cases of such failure and distortion among aluminium alloys must be discounted as referring to materials of really an essentially different type. It is the object of the present Note to draw attention to these facts in order to assist in removing what is undoubtedly a strong prejudice against useful and valuable materials of engineering.

* Paper read before the Institute of Metals, on Thursday, March 9.

† "Alloys of Zinc with Aluminium and Copper," Journal of the Institute of Metals, No. 1, 1920, vol. xxiii.

THE RUSSIAN NAPHTHA INDUSTRY.—Like all other Russian industries the naphtha industry has fared badly under the Soviet Government; the number of springs now in operation at Baku is hardly more than 15 per cent. of the pre-war number, and the figure is steadily decreasing. In the year 1913, some 3,600 naphtha springs were being worked in the Baku district, but already during the first revolutionary period of 1917 the number decreased, and when the Soviet Government started to nationalise this industry only about 1,500 springs were in operation. At the end of 1920 the number fell to 800, and during last year it was further reduced to 600. On the other hand, the number of idle springs has increased from 1,600 in 1913 to 4,600 at the present time. A vast amount of capital and labour will be required to start the idle springs working again. The fact that the output for last year amounted to about one-third of the pre-war output is explained by the unexpected increased yield of the springs in operation during the first half of 1921, an increase which in some cases amounted to as much as 500 per cent. of what was considered the normal yield. This fact has not been fully accounted for so far. After June last year there was a marked and rapid falling off in the production, from 67,200 tons in June to 31,150 tons for July and barely 20,000 tons for August. As late as 1920 there were still considerable stocks of refined naphtha, but by the end of last year these had been reduced to about one-fifth, due to the increased railway requirements. Matters in the Turkestan oilfields are still worse than at Baku, because of the wholesale migration of the people and the insecurity of the railways.

DANGEROUS ATMOSPHERES IN ABANDONED PITS.—The United States Bureau of Mines was recently informed that a geologist had been killed while entering a 90-ft. exploration shaft of a coal mine in California. He only carried an electric flashlight; he was heard to shout that he was coming up again, but he lost his grip on the ladder and fell down immediately afterwards. This, and another similar accident, are attributed simply to a deficiency of oxygen. Poisonous gases may, of course, be present in abandoned shafts, and they are particularly dangerous because they may accumulate locally. Carbon dioxide is generated in decaying timber and in some rocks; methane is evolved by the coal; carbon monoxide remains after explosions; sulphurous and arsenious gases may be liberated, and the atmospheric oxygen may be depleted to a dangerous extent by reacting with sulphur and other elements. The Bureau of Mines has therefore issued a memorandum, drawn up by Byron O. Pickard, on "Precautions to be Observed in Entering Abandoned Exploratory Shafts and Pits." The precautionary measures proposed are rather disappointing. To clear the air by raising and lowering a bucket or by churning it with an umbrella or a blanket, is a little primitive; miners should be provided with better safeguards. A mine air may be dangerous though clear and free of smell, and may be fairly safe in spite of turbidity and smell. The old suggestion, also made in the paper, that a man should not enter without having a rope round his body, which should be kept taut for signalling, and without posting two men at the top to haul him up, is more to the point. When work is to be resumed on disused parts, a little more might surely be done.

THE STILL ENGINE FOR MARINE PROPULSION.*

By ARCHIBALD RENNIE.

(*Concluded from page* 278.)

Trials.—With regard to the results obtained from the experimental engine on the test bed, it is scarcely possible to present these here in full or to give any detailed analysis of them—there is sufficient material in that for a paper by itself—but the general results and conclusions drawn from the trials will be traced.

It might be said, by way of introduction to this section, that there were no initial difficulties to face in getting the engine to function. It went off on steam on the first occasion on which steam was admitted to the cylinder, and similarly it commenced firing on the first occasion on which oil was injected into the cylinder; indeed, the ease with which it starts and its reliability in this respect are features of the engine. Almost at once, therefore, the trials resolved themselves into questions of power and fuel consumption, and in these respects it may be said that the early tests, as perhaps was to be expected, did not come quite up to expectations. They, however, pointed the way to improvement lying along the lines of better fuel-injection and more efficient scavenging on the oil side, and prevention of condensation on the steam side (independent high-pressure cylinder). These matters were, therefore, taken up in turn and dealt with until the desired results were obtained.

(*a*) *Fuel-Injection Tests.*—The fuel-injection question resolved itself into the determination of three main factors, namely, atomisation, distribution and penetration, with which was closely associated the question of cam shape. It was found that too fine a degree of atomisation could easily be obtained, and jets of this character, while giving excellent results at low powers, lacked penetrating power, and were most unsuitable at high powers. A jet of this type is shown spraying in Fig. 22. The spray was usually so fine that it floated through the test shop in the form of a light cloud. An average result with the best of these jets gave 127 brake horse-power at 106 r.p.m., and 0·368 lb. oil consumption per brake horse-power per hour. The combustion quickly became very bad when it was attempted to carry greater loads, 200 b.h.p., for example, having a consumption of 0·425 lb. per brake horse-power per hour. On the other hand, jets of too great penetrating power were found to be deficient in atomising qualities and to bombard the piston crown.

Over 60 different jets and fully half a dozen cams were tested, until finally it was determined that:—

1. Atomisation depends on the relation between the size of the hole and the pressure which can be maintained by the pump.

2. Distribution depends on the number of holes at the requisite angle necessary to cover the zone of maximum air-content of the cylinder.

3. Penetration depends on the diameter of the hole for a given degree of atomisation.

4. The fuel pump cam shape must be such that it will give pressure and quantities to meet the combination of atomisation, distribution and penetration found most suitable from experiments.

Having determined these points, in due time a suitable range of jets was found within the limits of which a fair degree of variation could be tolerated without appreciably affecting the fuel consumption. The jet found most suitable has one hole of $\frac{11}{128}$ in. diameter in its centre, surrounded by a ring of eight holes, each of $\frac{11}{128}$ in. diameter, lying at an angle of 45 deg. to the vertical. A jet of this type, having six holes in the circle, is shown spraying in Fig. 23.

Closely associated with the jet question was the question of the size of fuel-pump plunger. Three sizes of plungers were tried, but it was found that there was little to choose between them, the middle size of 1·25 in. diameter appearing on the whole to be the best.

(*b*) *Scavenging Air Tests.*—The scavenging problem presented greater difficulties to its solution.

Consideration of the size and disposition of the scavenging ports in the cylinder liner, as shown at Fig. 24, suggested at an early period in the trials that improved scavenging might be obtained by blocking up the extreme side ports, as shown at A and B. This was done, and a slight but distinct gain was recorded. A slightly higher scavenging air pressure as a result of this change had, however, to be maintained at the higher loads.

As the design of the piston-head in single piston-port scavenging engines has a large influence on the efficiency of the scavenging arrangements, attention was quickly directed to this matter, and it was soon agreed that the design of head fitted to the experimental engine was not altogether satisfactory. It is shown at 1, Fig. 25, and to simplify its construction was made symmetrical in form, the lip provided to deflect the scavenging air upwards being carried right round the piston head. This produced a double fault, firstly, by allowing a quantity of the incoming scavenging air to short-circuit round the cylinder to the exhaust ports; and secondly, by entrapping in the annulus formed by the lip and the cylinder wall at the top of the piston stroke a large proportion of the compression charge which could not be reached by the injected fuel. A new piston head of the form shown at 2, Fig. 25, was later made and fitted, and the results obtained with it, as measured by fuel consumption and piston temperature, showed a very decided improvement.

Trials are at present proceeding with a piston head of the design shown at 3, Fig. 25, and results from it to date promise quite a substantial gain—something of the order of 0·01 lb. to 0·015 lb.—in oil consumption per brake horse-power. The idea underlying the design of this head is that the size and shape of the lip are important factors influencing the scavenging efficiency. At a later period, and before the fitting of piston head No. 3, Fig. 25, the effective height of the scavenging ports in the cylinder liner was reduced by about 1¼ in. and a slight gain recorded. It was discounted a little, however, by the increased scavenging air pressure—about 25 in. to 30 in. of water—required from the blower and consequent increase of power.

In all these scavenging air trials, however, it was not found possible to assess correctly the value of each step in the improvement obtained, owing to the impossibility of accurately measuring the quantity of air delivered to the engine. The blower, not being of the positive type, could not be relied upon to deliver always the same quantity of air at the same speed with changing pressures. From a working point of vew that is not very important, as the speed can be adjusted to suit the engine load, but from a test point of view it left something to be desired.

(*c*) *Prevention of Condensation.*—The early trials, it has been said, showed that something was required on the steam side to reduce the amount of condensation experienced. Judged by the indicator cards, very considerable condensation was found to take place in the independent single-acting high-pressure steam cylinder, which is relatively large for the weight of steam passing through it, and in an endeavour to reduce the loss from this source, a light sheet-iron gas jacket was made and fitted round the cylinder. The gas supply was taken from the bottom of the Cochran boiler, and was allowed to escape to the atmosphere. Some improvement was effected by this jacket, but the loss from this cause has not been altogether eliminated. This question, however, is special to the experimental engine, and need not be further dealt with here. It will not be found in a multi-cylinder Still engine, where each high-pressure cylinder is combined with a combustion cylinder.

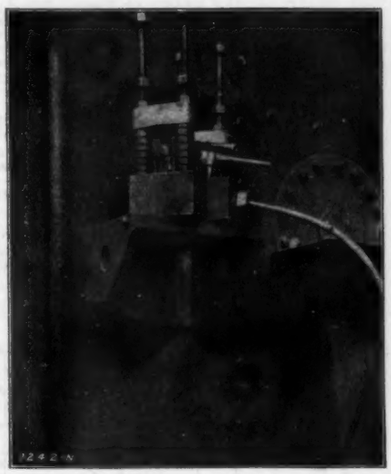


FIG. 22.

FIG. 23.

Fig. 24.

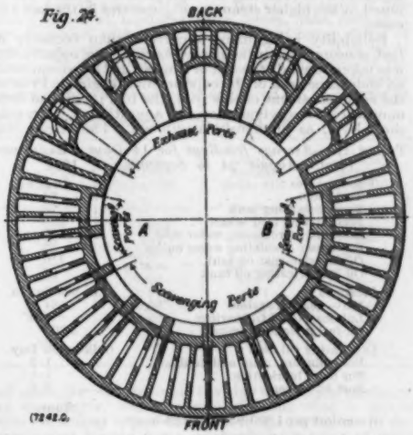


Fig. 25. TYPES OF PISTON HEADS.

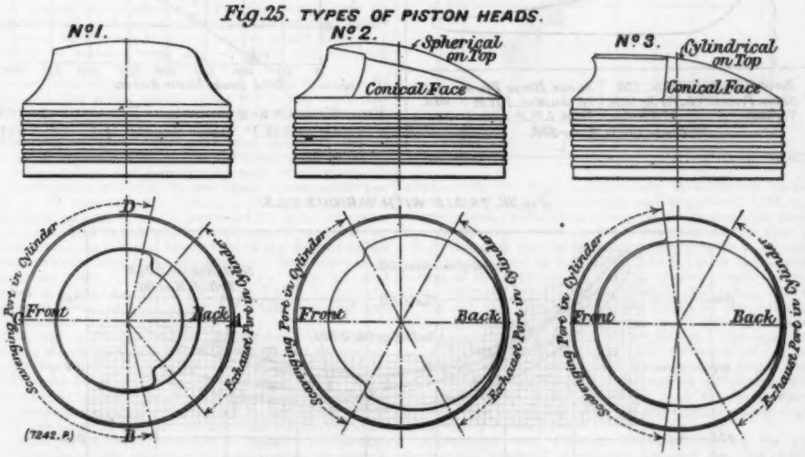


TABLE I.—*Particulars of Some Whole-Day Trials.*

—	6 Hrs. 5th Nov., 1920.	6 Hrs. 3rd Dec., 1920.	7 Hrs. 15th April, 1921.	6 Hrs. 10th May, 1921.	6 Hrs. 5th Oct., 1921.
Combustion M.E.P. ..	83·0	73·7	82·0	81·2	80·5
H.P. steam M.E.P.* ..	−2·47	2·47	2 53	3·8	3·8
L.P. steam M.E.P.* ..	6·47	5·11	4·53	6·23	6·01
Total M.E.P.	87·0	81·28	89·26	91·23	90·31
Revs. per minute	115·3	114·6	111·9	124·3	125·0
Total I.H.P.	347	324	345	392	391
Total B.H.P.	289	287	291	343	345
Oil per B.H.P. per hour ..	0·452	0·402	0·381	0·360	0·367
Mechanical efficiency ..	0·83	0·886	0·842	0·873	0·88
Brake load, in lb.	1,250	1,250	1,300	1,380	1,380

* Pressures referred to combustion cylinder.

(*d*) *Test Results.*—Nearly all the earlier trials were carried out over a period of from 2 hours to 3 hours, usually two trials in one day, but, whenever an improvement appeared to have been obtained, a whole-day

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, February 14, 1922 (slightly condensed).

trial of about 8 hours' duration was undertaken. Particulars of whole-day trials carried out on May 10 and 11, 1921, by a committee of French engineers, and on October 5 and 6, 1921, by Captain H. Riall Sankey, C.B., have already been published,* and will not be further referred to here. The leading particulars of these trials are, however, included in Table I for ready reference. With regard to the trials shown in this table, and referring to them in order of date, it might be mentioned that in the first case the independent auxiliaries were used, and were supplied with steam direct from the regenerator, and exhausted into the low-pressure cylinder casing. The result shows that the high-pressure cylinder was starved of steam and was doing negative work. In the second case the auxiliaries were worked from an independent steam supply, and exhausted direct into the condenser. In the third case the independent auxiliaries were cut out, and the engine-driven auxiliaries were used. In the fourth case (French trial) the high-pressure cylinder was gas jacketed in the manner already described, and in the last case (Sankey trial) a heavier grade of shale oil (Lucigen) was used than in the other trials. The gain from jacketing the high-pressure cylinder can be noted in the higher steam mean-pressures in the last two cases.

Reliability being more important than economy of fuel consumption in a marine engine, the opportunity was taken towards the end of August, 1921, to commence an endurance trial of the experimental engine. Prior to the commencement of this trial, the fuel pump had been moved from the cylinder level to a position at the crankshaft level, as previously mentioned. The engine was

TABLE II.—*Average Readings for 14 Days. Endurance Trial. August 24 to September 7, 1921.*

Temperatures :	Deg. F.
Test room	62
Feed-measuring tank	73
Feed leaving feed heater	229
Condenser circulating water inlet	57
Condenser circulating water outlet	83
Oil in valve-gear oil tank	110
Oil in lubricating oil tank	97
Pressures :	Lb. per Sq. In.
Valve-gear oil system	384
Lubricating oil to bearings	8·9
Oil-fuel injection pressure	5,300
Lubricating Oil used :	Gallons per Day.
For cylinders, main and auxiliary	1·5
For hand lubrication	1·1
Lost by leakage	2·3
	Tons.
Water lost per 1,000 b.h.p. per 24 hours	1·41

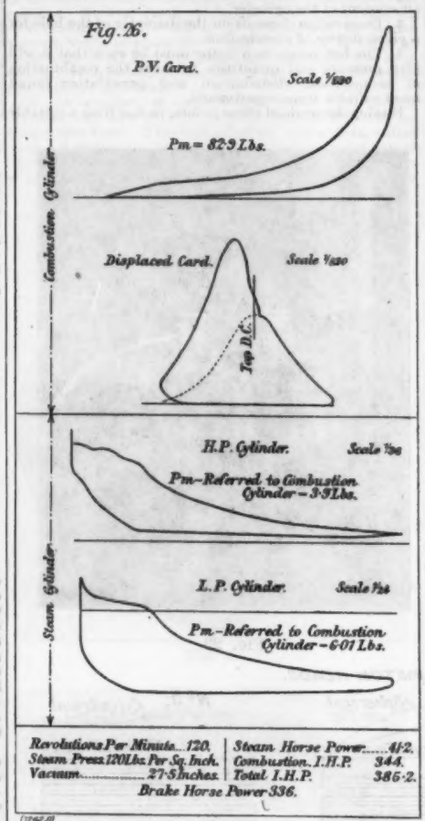
run continuously for 14 days and nights, except for two short stops, both of which were occasioned by the breaking of the fuel-valve spring. In a multi-cylinder engine a stop would not have been necessary to change the spring, but in this single cylinder engine it was deemed advisable to do so. The trial was undertaken at about mean-service power, primarily to demonstrate the engine's reliability and without special regard to fuel consumption, whilst the conditions were made to approximate as closely as possible to those usually met with on board ship. Results are given in Table II. The means of hourly readings which were taken, demonstrated the great steadiness of the engine performance throughout the whole period of the trial. The trial indeed, from the point of view of the men on watch, was as monotonous and devoid of incident as a steam-turbine engine trial.

TABLE III.—*Particulars of Experiment to Determine Temperature of Piston Head in Neighbourhood of Topmost Ring.*

Position.	Metal.	As Put In on 12–11–20.	As Taken Out on 14–12–20.	Remarks.
A.	Aluminium	Two pieces of $\frac{7}{16}$ in. sq. section by $\frac{1}{4}$ in. long	Intact with slight brown surface colour	—
B.	Tin	Two balls of tin foil	Grey dust	Oxidised.
C.	One piece Aluminium	Aluminium of $\frac{7}{16}$ in. sq. section by $\frac{1}{4}$ in. long	Intact	—
	One piece zinc	Zinc strip bent double	Intact	—
D.	Zinc	Eight thin strips	One ball about $\frac{1}{16}$ in. diam. and a coarse powder	Fused.

On the conclusion of this trial, and of most of the whole-day trials already referred to, the engine was opened out for examination, particularly as to the condition of its combustion side, and on all occasions subsequent to the fitting of the piston head shown at 2, Fig. 25, it was found to be in a satisfactory condition. The original piston head (No. 1) showed signs of having been overheated, largely because of the severe treatment to which it was subjected during the course of the fuel-jet trials. In this connection, it may be of interest to note that by fitting a sight hole in the door on the front of the scavenging belt, as shown at Z, Fig. 1, the movement of the piston head past the scavenging ports could be seen and its temperature surmised. An attempt was made at one time to measure the temperature of No. 1 head by an optical pyrometer, but as the reading fell outside the lower limit of the scale of the instrument, which was 700 deg. C., no result could be obtained. At the same time, when observing the piston head, the tail end of the flash of the exhaust gases, having the appearance of bluish white flame, could occasionally be seen disappearing out of the exhaust ports.

Whilst on this question of piston-head temperature, it may be observed that four small holes were drilled in the circumference of the original piston head—that shown at 1, Fig. 25—just above the topmost ring, into which small pieces of metal, having various melting points, were inserted and the holes plugged. They were kept in for about one month, during which the engine was running nearly every day, and at the end of that time taken out, with results which showed that the average temperature



of that piston head just above the topmost ring was about 750 deg. F. Particulars of this experiment are given in Table III. The metals used were pure, and had the following melting-points :—

	Deg. C.	Deg. F.
Aluminium	658	1,212
Zinc	420	788
Tin	232	450

Concerning the 14 days' endurance trial, the following extract is from the report of Lloyd's representatives, who were present every day during the trial :—"Upon the completion of the endurance test, the engine was submitted for examination. The cylinders, piston, piston rod, and the feed-water filter were opened out for examination, and found in good condition. It was not considered necessary to examine the crankshaft, crank-pin, or the piston-rod crosshead. The boiler was examined internally, and found good and absolutely free from oil.

"From the start to the finish of the trial during the 14 days' continuous working the engine ran excellently ; no trouble was caused by any part other than the breaking of the fuel-valve spring on two occasions (a contingency common to all internal-combustion engines), and the partial loss of vacuum on one occasion.

"From the records* given above, it will be observed that there is great regularity as regards the revolutions and the brake horse-power, and, in conclusion, we would state definitely that not only did the engine run well throughout the trial but was in thoroughly good condition at the finish."

Typical indicator cards taken on this trial are shown in Fig. 26. The oil fuel used on all trials up to September, 1921, was shale, having a calorific value of about 19,300 B.Th.U. gross (18,240 net) and a specific gravity at 60 deg. F., varying from 0·85 to 0·87.

During the course of all these trials, many samples of scavenging air, compression charge, and exhaust gases were taken and analysed. Some average results as taken near the finish of the 14 days' trial are given in Table IV.

TABLE IV.—*Analyses of Gases.*

——	Scavenging Air.	Compression Charge.	Exhaust Gases Entering Regenerator.	Exhaust Gases Leaving Feed Heater.
	per cent.	per cent.	per cent.	per cent.
Carbon dioxide	0·3	0·2	4·8	4·6
Oxygen	20·2	20·35	15·0	15·1
Carbon monoxide	Nil.	Nil.	0·2	0·2
Nitrogen	79·5	79·45	80·0	80·1
	100·0	100·0	100·0	100·0

The analyses of the scavenging air and compression charge show a high scavenging efficiency, the composition of these gases approximating to the composition of air, with a very slight increase of carbon dioxide. The analyses of the exhaust gases indicate that the combustion of the carbon and hydrogen of the fuel, so far

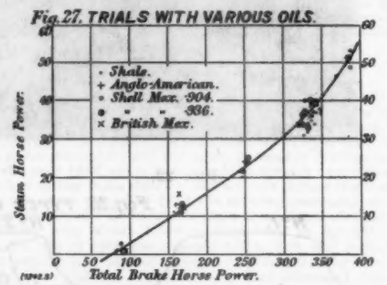
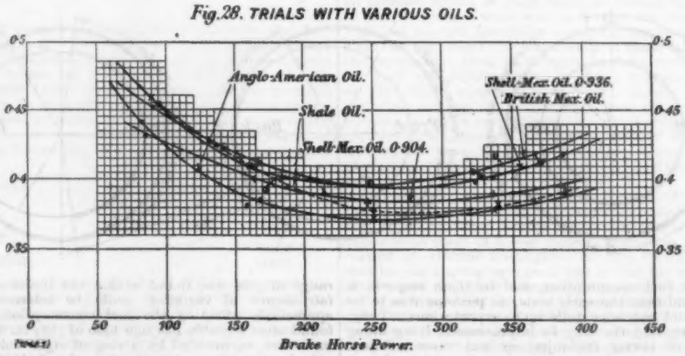


FIG. 27. CURVE SHOWING RELATION BETWEEN TOTAL B.H.P. AND STEAM H.P. AT VARIOUS LOADS.



as it is taking place, is complete, very little of the lower oxide of carbon remaining in the gases.

Samples of feed water were tested for oil during the course of this trial ; results are given in Table V.

TABLE V.—*Feed-Water Tests for Oil.*

Date.	Grains per Gallon.	Per Cent.
5–8–21	Nil	Nil
29–8–21	12·40	0·0155
31–8–21	7·30	0·0092
5–9–21	14·44	0·0178
7–9–21	15·62	0·0193

All these samples were taken from the feed tank before the water was filtered. A sample taken after filtration on the fourteenth day of the trial contained 3·03 grains

* ENGINEERING, September 2, 1921, and *The Motor Ship*, October, 1921. ENGINEERING, February 10, 1922.

* Records accompanying the report.

per gallon, or 0·0037 per cent., and this is perhaps a better estimate of the amount of oil in the feed water. All these samples on test were found to be wholly lubricating oil. It may be said that no trace of fuel oil has been found at any time in the feed water. Neither has any scale, sediment, or deposit been found on the cylinder liner and other jacketed spaces, although carefully searched for.

(e) *Weight of Steam Generated on Test.*—The quantity of steam generated from waste heat by the single cylinder is 800 lb. per hour at 120 lb. pressure per square inch when the combustion cylinder is working with about 80 lb. mean pressure, equal to a normal load of about 340 b.h.p. It increases as the load is increased, and falls away as the load is reduced, until, at about 35 lb. mean pressure in the combustion cylinder, just sufficient heat is being recovered to equalise the radiation losses. This is quite to be expected, for as the load is reduced the quantity of fuel oil burned is less, and the waste heat available for steam generation is, therefore, also less. At the same time it should be noted that, at mean pressures of about 49 lb. and under in the combustion cylinder, no steam is necessary for piston cooling, the rate of heat transfer by contact with the cylinder wall being sufficient to keep the piston cool. During all the trials it was noted that whenever the combustion side fell off in efficiency, as, for example, when different fuel jets were being tried and combustion was not good, the steam side always improved, responding at once to the increased fuel consumption.

With regard to the proportion of power obtained from the steam side, it will be observed that this amounts to about 12 per cent., of the total horse-power at full normal load. This, for obvious reasons, is not so high as would be obtained from a multicylinder engine, when from 15 per cent. to 20 per cent. may be expected. A curve showing the relationship existing between total brake horse-power and steam horse-power in the experimental engine is given in Fig. 27.

(f) *Tests with Heavy Oils.*—A series of 8-hour trials using different grades of heavy oils was commenced on October 20, 1921, and the results are plotted in Fig. 28. No adjustments were made to the engine prior to or during these trials, the same cam and fuel-valve settings as had been found most suitable for shale oil were used throughout. It was noticed, however, that as each grade of oil was succeeded by a heavier one, the volumetric efficiency of the fuel pump fell off, and consequently the point of injection gradually became later. The results, therefore, are not so good as they would be with proper settings. When, however, they are equated to a common standard net calorific fuel value, they fall quite closely into line with each other, showing that the overall efficiency is not much affected, as between the different oils. Particulars of the oils used are given in Table VI.

Following on these trials, the engine was again opened up for examination of the internal parts, and was found to be in excellent condition. The piston rings were all free and clean, and no carbon deposit or other evidence was found to suggest that the engine would have any difficulty in running with any of these oils for long periods.

Before concluding this section on trials, it might be mentioned that many trials—not a few being whole-day trials—were run, with very satisfactory results, using a gear designed to increase the charge weight of air in the combustion cylinder. The gear was operated by oil pressure from an extension of the system for working the steam valves, and gave an average improvement in oil consumption of 0·015 lb. per brake horse-power per hour at all powers. As, however, the gear was of a temporary nature, it is not proposed to enter into any description of it in this paper. Mention is made of the matter merely to indicate the extent of the improvement in fuel consumption to be obtained by its adoption in permanent form. The trials run on May 10 and October 5, 1921, and referred to in Table I, are the only ones given in this paper in which this gear was in operation.

With regard to the conduct of all trials, it might be said that the refinements of the laboratory test-room were largely absent, the primary aim being to establish results which could be repeated on a commercial scale. It is believed that that aim has been achieved, and although fuel consumptions of less than 0·35 lb. per brake horse-power per hour at full normal load have been obtained over short periods, it is not felt in the meantime that that figure represents the everyday performance of the engine. Mention of the fact is made here only to show that the limits of economy, even in the single-cylinder experimental engine, have not yet been reached. It is fitting here also to make due acknowledgment of the most valuable advice and assistance received throughout the whole course of the trials from Mr. William Joseph Still, the inventor of the Still system.

As a last remark concerning the trials, it might be stated that, except where considered necessary for clearness, all matters relating to improvements in design, and anticipated improvements in consumption resulting therefrom, have been excluded from this paper, but it will readily be understood that many things have been learned during the last eighteen months which point the way to these ends and will be given effect to in future engines.

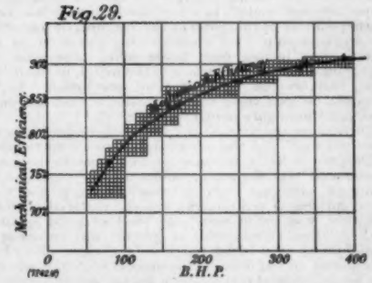
Large Powers.—Like all other oil engines, large powers in the Still engine are obtained by multiplying the number of cylinders. The engine lends itself very readily to construction in groups of three cylinders, and two or three groups may be arranged on one line of shafting. In each group one cylinder on its steam side is arranged to work as a high-pressure cylinder, and the two others as low-pressure cylinders. Groupings of four and five cylinders may also be arranged quite easily; in these cases one high-pressure cylinder will exhaust into three or four low-pressure cylinders respectively, the correct volumes being obtained by varying the cut-offs. Taking, for example, a group of three cylinders, it will be seen that, as compared with the single-cylinder experimental unit, the steam available for compounding will be that generated from the products of combustion of the oil sides of these three cylinders. The high-pressure cylinder of the group will pass all this steam through it, and each of the two low-pressure cylinders will deal with 50 per cent. more steam than the quantity generated by its own combustion side. This point is of considerable importance, for, as has been mentioned previously, dependence is placed on the steam to keep the piston cool. In this and in other respects the single-cylinder unit that has been described is at a distinct disadvantgae, and improved results may, therefore, be looked for in multi-cylinder engines. It might be added with regard to the efficiency of the steam-cooling arrangements for the piston that the question is really one of cylinder power-rating; if that is kept high, the piston temperature will also be high.

It is known that the specific heat of steam is lower than that of water, and that it is not in consequence such a good cooling agent. But it should be remembered in connection with its use in the Still engine that, when acting as a cooling agent, it is expanding and trying to condense, hence it tends to absorb more and more heat in the process, so that its specific heat is a variable quantity, and is always approaching that of water. It becomes, however, a question of practical experience whether in the Still engine there is sufficient steam available for cooling purposes, and experience with the single-cylinder experimental engine has shown that there is. At the same time the trials have also shown that in the Still engine the piston temperature must in the meantime be regarded as the factor which limits the power-rating of the cylinder, and in the single-cylinder engine this power has been found to be about 340 b.h.p. Were it not for this factor the power-rating of the cylinder might be considerably increased, as all the other parts of the engine could stand a higher rating. For example, the cylinder liner, which in most other types of oil engines is, equally with the piston, the limiting power factor, due to heat stress arising from temperature difference, is in the Still engine of such a design that the heat transmission rate through it at its present normal rating could quite safely be doubled.

TABLE VI.—PARTICULARS OF FUEL OILS USED IN TRIALS REFERRED TO IN FIG. 28.

	Scottish Shale Oil (Lucigen).	Anglo-American Diesel Oil.	Shell Mexican Diesel Oil.	Shell Mexican Boiler Oil.	British Mexican Boiler Oil.
Specific gravity at 60 deg. F.	0·879	·884	·904	0·936	0·94
Flash-point, deg. F.	266	198	194	188	208
Viscosity at 60 deg. F. (Redwood No. 1)	96 Secs.	71 Secs.	145 Secs.	—	—
Viscosity at 120 deg. F. (Redwood No. 1)	40 Secs.	39 Secs.	53 Secs.	200 Secs.	1,380 Secs.
Ash, per cent.	Trace	Trace	0·08	Trace	0·30
Sulphur content, per cent.	0·36	0·4	1·84	3·01	3·68
Calorific value, B.Th.U. (gross)	19,426	19,334	19,037	18,581	18,362
Calorific value, B.Th.U. (net)	18,065	17,970	18,000	17,430	17,300
Minimum Temperature required for complete combustion in air, deg. F.	698	680	770	824	860

Fig. 29.



Advantages and General Remarks.—Owing to the favourable thermal conditions created by the high-temperature jacket water surrounding the combustion cylinder, it becomes easy in the Still engine to burn oil at a relatively low compression-pressure. This is effected by the incoming air taking up heat from the cylinder wall for the greater part of the compression stroke, instead of losing heat to the wall for nearly the whole of the stroke, as is usual in most other heavy oil engines. The result is to produce a compression charge with a high temperature and a low-pressure at the end of the stroke, and so to ensure the ignition of the fuel oil on its injection into the cylinder. The results, from some small engines of the Still type which have been constructed, show that firing has been regularly maintained when running with a compression pressure as low as 180 lb. per square inch. In the experimental engine the lowest compression pressure actually worked with was 250 lb. per square inch, but as a better efficiency is obtained with a compression pressure of from 300 lb. to 350 lb. per square inch, a pressure within these limits is aimed at. The facility with which the engine can run firing at very low compression pressure affords an ample working margin for possible reduction in the designed pressure, due to leakage past the piston rings, slow running, or other cause, and makes the Still engine what the Diesel engine is not—a flexible engine. No misfire is known to have occurred with this engine, the fuel igniting instantly on its injection into the cylinder. Neither have any pre-ignition difficulties been experienced.

It may be thought that a loss in efficiency is suffered by limiting the compression pressure to about 300 lb. to 350 lb. per square inch, as it is well known that, theoretically, thermal efficiency increases with the compression ratio. But in order not to sacrifice efficiency in this way, the initial stages of combustion in the Scott-Still engine are completed at approximately constant volume. Further, it must not be overlooked that the margin of safety in a cylinder is a function of the compression pressure, hence, if from any cause the pressure due to combustion in a cylinder is doubled, the extra loads put upon an engine working with a compression pressure of 500 lb. per square inch are much more serious than in the case of one working with a compression pressure of 300 lb. per square inch. Engines, therefore, such as the Still engine, which work with a low compression pressure are potentially safer than those which do not.

There is a marked absence on the Scott-Still engine of the mass of moving mechanism usually to be found on a heavy oil engine, as, owing to the automatic action of the fuel injection valve, and the oil operation of the steam valves, all layshafts, cams, levers, links, rods, &c., are dispensed with, the only cams used being those of the crankshaft for operating the fuel pumps. The use of steam also, for piston cooling, dispenses entirely with the somewhat troublesome and elaborate gear necessary where oil or water cooling is employed. The absence of all these gears is reflected in the high mechanical efficiency of the engine, which, notwithstanding that it drives every auxiliary required for its own operation, except the scavenging blower, has a mechanical efficiency of from 88 per cent. to 90 per cent. at full normal power, see Fig. 29.

The engine being double-acting, due to the operation of oil and steam on opposite sides of the piston, an improved turning-moment diagram is obtained, and lubrication of the principal bearings is facilitated.

A valuable feature of the Still engine, from the sea-going engineer's point of view, is the power it gives him of instantly supplementing the steam supply, and increasing the horse-power of the engine in any case of emergency, without adding to the stresses on the working parts. This result is obtained by lighting one or more burners in the regenerator, which is always carrying a head of steam generated from waste heat. This feature, if rightly appreciated, must also appeal to the shipowner as it reacts on the size and first cost of the engine. It is well known that the marine steam engine, and the oil engine, too, for that matter, is usually larger than is required for the normal power and speed of the vessel in which it works. This excess of power, which sometimes is as much as 50 per cent. above normal, is provided as a safety measure and insurance against some emergency condition arising at sea. It follows that the machinery installation must be designed to give this excess power, with its increased cost, weight and space required; whilst at the same time it is known that, after the trial trip, the engines in question will run at normal power, and indeed may never again be called upon to repeat the trial trip performance. It will be seen at once that a Still engine installation may safetly be designed for normal power alone, and the additional power, when required, obtained from added steam by lighting the burners in the regenerator. A distinct saving in first cost, weight and space occupied may, therefore, be obtained by allowing for this feature in the estimate.

In this connection, it is of interest to note that opportunity was taken one day when running turbines in the works to make a test with the Still experimental engine using added steam. A 2½-in. diameter pipe connection was led from the turbine supply to the Still engine. At the time the Still engine was developing normally 380 b.h.p. at 125 r.p.m., and without any alteration other than the added steam, the power increased to 465 b.h.p. at 132 r.p.m. The trial was of half an hour's duration only, as the added steam was very wet (the engine was 550 ft. away from the boiler), and carried over with it a large quantity of water. The trial had on that account to be cut short. It is to be noted that this additional power or overload from added steam is obtained without any increase in the stresses on the working parts, as already mentioned, these all being, under maximum steam load, well below the stresses due to the combustion load.

Owing to its being in part a steam engine, the Still engine possesses all the kindly cushioning qualities and flexibility of a steam engine in starting, in manœuvring, and in running, and indeed in an extreme case, should the oil side fail, the engine may quite well continue running on steam alone for any desired length of time.

It may be thought that a Still oil engine installation on board ship will be complicated, as it must necessarily comprise the usual oil-engine auxiliaries plus the usual

TABLE VII.—COMPARATIVE LIST OF AUXILIARY MACHINERY.

Diesel Oil-Engine Auxiliaries not Required in Still Oil-Engined Ships.	Still Oil-Engine Auxiliaries not Required in Diesel Oil-Engined Ships.	Steam Auxiliary Machinery frequently found in Diesel-Engined Ships corresponding to the Steam Auxiliaries found in Still-Engined Ships.
Air Compressor for blast air injection.	Main Condenser.	Donkey Boiler.
Air Compressor for starting (oil driven).	Main Air Pump.	Donkey Boiler Feed-Pump.
Auxiliary Air Compressor (steam, paraffin or hand-driven).	Main Circulating Pump.	Oil-Fuel Burning Plant.
Air Bottles and Reservoirs for starting.	Regenerator.	Sometimes also :
Jacket Cooling-Water Circulating Pump.	Regenerator Circulating pump.	Auxiliary Condenser.
Piston Cooling-Water Circulating pump.	Regenerator Feed-Pump.	Auxiliary Condenser Circulating-Pump.
Cooler for Cooling Water.	Feed-Water Heater.	
Circulating-Pump for Sea Water to Cooler.	Valve Gear Operating Pump.	
Exhaust Silencers.	Oil-Fuel Burning Plant.	

steam engine auxiliaries. This is not really so. Table VII gives, in column 1, a list of auxiliary machinery usually found on Diesel oil-engined vessels which will not be found on Still-engined vessels, and in column 2 a list of auxiliary machinery required by the Still-engined ship not to be found on Diesel oil-engined ships. Column 3 gives a list of steam-driven auxiliary machinery frequently found on Diesel oil-engined vessels, and not always included in a list of the auxiliaries, which correspond more or less to the steam auxiliary machinery in Still-engined vessels. In considering these lists, some regard should be paid to the relative sizes and costs of the auxiliaries. For example, in a 6,000 b.h.p. Still installation, the combined surface of the two main condensers will be less than the surface of the single cooling water cooler provided in a corresponding Diesel installation of 4,500 b.h.p. It should be borne in mind also that the steam auxiliaries required by a Still installation are, relatively to the total power developed by the main engines, very small, simple and cheap ; that they are continuously in use for the development of power ; and that they displace relatively large and costly starting auxiliaries in the usual Diesel installation.

The utilisation of the waste heat of combustion and the return in power obtained from it go far to explain the undoubted economy of the engine. In normal full-power running this return in power may be expected to equal at least the power absorbed by engine friction.

In concluding this paper, it might be said that the history of prime movers in general has been the history of a striving after increased thermal efficiency or, more directly, fuel economy. Advances in fuel economy have often brought attendant troubles in their train, making for unreliability, and sometimes also the glamour of thermal efficiency has obscured the fundamental vital consideration of operative efficiency.

It is claimed for the Still engine that it obtains an economy quite 10 per cent. better than that of any other present-day heavy oil engine without violating in any way the principles of reliability and operative efficiency just referred to. In other words, the Still engine marks a big step forward thermodynamically, without at the same time marking a backward step mechanically. Hence, by reason of its high thermal efficiency and simple mechanical properties, it is peculiarly fitted for the work required from a prime mover for the propulsion of ships at sea.

BOILER EXPLOSION AT A COLLIERY.

A PRELIMINARY INQUIRY has been conducted by the Board of Trade as to the cause and circumstances of a boiler explosion which occurred on July 30 last at the Park Slip Colliery, Aberkenfig, Glamorganshire, owned by the Messrs. North's Navigation Collieries, Limited. Fortunately no person was injured by this explosion, which was comparatively simple in character.

The boiler—we learn from the report of Mr. Gilbert J. Isaac, one of the surveyors to the Board of Trade, who made an inspection after the failure occurred—was made of steel, and was of the vertical type, fitted with cross water-tubes in the firebox. It was 4 ft. in diameter and 11 ft. in height. The shell was formed of two strakes of plating $\frac{1}{2}$-in. in thickness, the longitudinal and circumferential seams being lap-jointed, the former double riveted and the latter single riveted. The crown plate $\frac{11}{16}$ in. in thickness, was dished and flanged inwards for attachment to the cylindrical shell and outwards for attachment to the uptake. The firebox was 3 ft. 6 in. in diameter at grate level, tapering upwards to 3 ft. 3 in. in diameter in way of the fire crown plate attachment. The thickness of plate was $\frac{7}{16}$ in., and it was enlarged in diameter for attachment to the boiler shell plate. The vertical seam was lap-jointed and double riveted, and the circumferential seams were lap-jointed and single riveted. The cross water-tubes, four in number, each 9 in. in outside diameter, having a thickness of $\frac{1}{2}$ in., were welded longitudinally and flanged and riveted to the firebox.

After giving a few more details and a list of the fittings Mr. Isaac states that the boiler was designed for a working pressure of 80 lb. per square inch, at which pressure the safety valve was adjusted to lift. The boiler was made at Loughborough in 1918, and no repairs appear to have been made previous to the date of the explosion. The boiler was insured with the London and Scottish Assurance Corporation, and was inspected in February, 1920, when one of their inspectors made a thorough examination. It was also examined by the firm's engineer-fitter-in-charge in the owner's employ, in March, 1921.

The lowest water-tube fractured for a length of about 11$\frac{1}{2}$ in., opening to a maximum of about $\frac{1}{4}$ in. Through the aperture thus formed water and steam escaped into the firebox and thence through the firedoor and ashpit openings into the boiler house.

The explosion appears to have been due to defective welding at the longitudinal seam in the process of manufacture of the tube.

In his general remarks Mr. Isaac enters at some length into the early history of the boiler, which was tested to a pressure of 175 lb. per square inch when Messrs. North were about to instal it at the colliery. It was then set to work and was insured and inspected by the London and Scottish Corporation.

It was stated by the engineman in charge that at the time of the explosion the water level in the boiler was about 1 in. from the top of the visible portion of the gauge glass, and the pressure registered by the steam gauge was about 80 lb. per square inch. The water gauge mountings had been tested about half an hour before the explosion occurred, and it had been noted earlier in the day that the safety valve lifted freely at 82 lb. per square inch. The engineman was fortunately outside the door when the tube ruptured, and the first indication he had that something unusual had occurred was the sound of the explosion, which appears to have been a loud one. It was then noticed that steam was issuing from the boiler house in large volumes, and it was some little time before entrance could be made. On examination it was found that the lower cross tube in the firebox had ruptured, as already stated. The tube was, as usual, so fitted that when in place in the firebox the weld was approximately on the top centre, away from the impinging action of the flames.

The tube was cut out of the boiler and a more thorough inspection was made. It was difficult to ascertain from the appearance of the metal at the fracture, the nature of the workmanship done when welding the seam, as the examination having been made some days after the explosion occurred the surface of the metal, in the meantime, had become discoloured by oxidisation. As far as could be seen there was no evidence that the parts were not thoroughly joined together.

Particulars are given of the test of two pieces selected from the tube, and the report states that unfortunately in the case of No. 1, fracture occurred outside the gauge limits, and the elongation could not be satisfactorily obtained. Judging from an examination of the fractured surfaces it was thought that the material of which the tube was made was mild steel of good quality. No. 2, the circumferential piece, was necessarily straightened at a blood red heat and then allowed to cool slowly on the floor. This process probably affected the actual original textile strength, the report states, to a small extent.

The percentage of strength of the welded seam as compared with that of the solid plate of which the tube was made was therefore 63·4. This figure is the strength at weld of that portion of the tube which resisted the tendency to burst under the working pressure. It therefore appears reasonable to assume that the portion of the weld which failed in the first instance under ordinary working conditions must have been very considerably less in strength than 63·4 per cent. as compared with the solid plate.

Mr. Isaac concludes his report by saying that the percentage of strength of good welded seams is usually, found to be considerably more than that obtained above and judging from the structure of the fractured surfaces of No. 2 test piece it is thought that although the metal was apparently thoroughly joined together the material had been so treated during the process of welding, probably by overheating, as to render the weld unreliable.

Mr. Carlton in his "Observations as Engineer in Chief," adds the following :—"The explosion dealt with in this report was the result of the failure of a welded steel tube under ordinary working conditions. The failure was probably due to a latent and unsuspected defect in the weld or in the metal in its vicinity.

"The welding of a seam by the ordinary fire process in successive stages along the length of such a tube, entailing frequent applications of heat to the parts about to be welded, requires skill and experience if overheating and consequent deterioration of the material are to be avoided.

"Fortunately the results of the explosion were not serious."

NEW NAVAL AVIATION MOTOR.—The Danish Naval Yard in Copenhagen has just completed the construction of a new aviation motor, says the *Danish Foreign Office Journal*, and trials already made have demonstrated it to be reliable and of particularly good pulling power. Two of these motors are to be installed in Brandenburger hydroplanes, and if experimental flights confirm the experience of the trials hitherto made it is the intention of the Naval Yard to construct planes especially adapted to this motor. Provisionally the yard is to construct three new Brandenburger hydroplanes which are to be equipped with the new motor.

CATALOGUES.

Roofing Slabs.—Reinforced concrete slabs for the roofs and sides of buildings are described with fully illustrated details of fixings in a catalogue issued by Messrs. Thomas Furniss and Co., Limited, Little Royd, Huddersfield.

Tools.—A catalogue of taps, dies, reamers, end mills and counterbores received from Messrs. W. L. Brubaker and Brothers, 50, Church-street, New York, extends to 168 pages, nearly all filled with tables of sizes. It is a very comprehensive list.

Wireless Apparatus.—A considerable range of fittings and instruments required for experimental and other installations of wireless telegraphy is given in an illustrated catalogue of 64 pages issued by Mr. H. W. Sullivan, Winchester House, London, E.C. 2.

Wind-Driven Electric Generators.—A catalogue illustrating windmills for the generation of electric current has been sent to us by Messrs. F. A. Wilkinson and Partners, Limited, Hatfield, Herts. Some particulars of these plants will be found on page 282 of our last volume.

Air Screws.—A catalogue of metal air screws is to hand from the Metal Air Screw Company, Limited, Regent House, Kingsway, London, W.C. 2. In these air screws the boss is a separate standard part with two, three or four branch sockets on which the blades are fixed and on which they may be turned for adjustment of pitch.

Pneumatic Tools, &c.—New editions of their sectional catalogues of rock drills, hammer drills, electric welding plants and steam and belt-driven air compressors have been issued by the Consolidated Pneumatic Tool Company Limited, 170, Piccadilly, London, W. 1. All these catalogues are illustrated, fully descriptive and contain useful technical information.

Electric Power Transmission.—A catalogue specially dealing with long-distance transmission of electric current by overhead lines carried on masts or towers has come to hand from the British Aluminium Company, Limited, 109, Queen Victoria-street, London, E.C. 4. The technical information relating to transmission and the mechanical requirements of mast erection, fixing cables, &c., is given in 48 pages of illustration and text. A steel cored aluminium strand has made it practicable to increase the maximum spacing of the masts from 600 ft. to 1,000 ft., effecting a very great saving in capital cost.

Capstans.—The application of the electric motor to capstans allows the whole of the mechanism to be placed under the ground level in a shallow cast-iron box, leaving only the bollard and operating pedal above the surface, thus making the hauling of trucks at railway sidings and in various yards and works very convenient. Messrs. Thomas Broadbent and Sons, Limited, Huddersfield, send a catalogue describing an electric capstan for general work, including use on shipboard, in which all the practical conditions of service are taken into account ; in fact, the whole scope of this appliance seems to have been widened by the newer design.

Pressed Steel Tanks.—We have received from Messrs. Thomas Piggott and Co., Limited, Atlas Works, Spring Hill, Birmingham, a pamphlet illustrating and describing their method of constructing tanks from pressed steel plates, 4 ft. square. We note that the firm has recently received an order for one of these tanks to hold 500,000 gallons and measuring 140 ft. long, 48 ft. wide and 12 ft. deep. This particular tank will only be required for a few months' service, and when this is completed it will be taken down and re-erected elsewhere as several separate tanks of smaller capacities. The firm's unit system of construction, described in these notes on page 807 of vol. cxii, renders the above-mentioned operation a simple, expeditious and economical one.

Michell Bearings and Accessories.—The value of the Michell bearing is now established beyond the reach of argument, but though the principle is thoroughly sound, it has not always been intelligently applied. In the Michell bearing book issued by Michell Bearings, Limited, of South Benwell, Newcastle-on-Tyne, pains are taken to explain the details of construction which have been found most reliable in practice. A supplementary circular has also been issued, calling attention to further details. The plan of supporting the blocks on a single point is here strongly reprobated. The blocks should have line and not point contact. They thus deform less, and the conditions approximate more closely to the theoretical ideal than is possible with point contacts. The catalogue contains also an excellent description of the physical theory of the device. A comparatively new departure described here is the Michell journal bearing. One of these, designed to carry a load of 33·8 tons, measures but 16 in. in diameter by 14 in. long. The designed running speed is 500 r.p.m. to 900 r.p.m. A neat arrangement in which a Michell bearing and Michell thrust block are combined in the same housing, is also illustrated and described, and in another form the pads to a thrust bearing are supported by small hydraulic cylinders, which enable the total propeller thrust to be readily measured under all conditions of running. The firm make a considerable range of standard slippers, of which full particulars are given in the catalogue, which includes, further, some useful hints on the supply and distribution of the lubricant. In high-speed work the importance of keeping the oil clear from the edge of the collar is emphasised. If the latter is allowed to dip into oil contained in a well, great heat may be developed. It may be added that a similar precaution has been found necessary in the case of the couplings commonly used to connect up a steam turbine with its generator. Unless the space in which this coupling runs is thoroughly drained, serious over-heating of the oil is very likely to occur.